University of Nevada

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Investigation of the Murray Landfill - An Uncontrolled Hazardous Waste Site

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by

Troy Calvin Scott
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The thesis of Troy Calvin Scott is approved:

John W. Bird

Thesis Advisor

Jon A. Epps

Department Chair

John Neller

Dean , Graduate School

University of Nevada

Reno

December 1985

Abstract

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Troy Calvin Scott

Murray Landfill was a refuse site for the City of Springfield , Missouri for six years. The City landfill prior to Murray has been determined to be an uncontrolled hazardous waste site and is included in the National Priority List for Superfund clean-up action. Additionally, Murray Landfill has been proposed by the City as a site for construction of a new Wastewater Treatment Plant. This thesis is an analysis of the general nature of hazardous waste at the site, its sources and paths of transport and the possible effects of this proposed construction.

In examining the sources of any hazardous waste, landfill history, chronology and probable operating procedures are the foremost indicators of any possible contamination . A conceptual model of Murray Landfill is developed and evaluated, while the legal implications of operating this landfill and continuing with the proposed construction are reviewed , and recommendations for a remedial investigation under the guidance of the U.S. Environmental Protection Agency are outlined.

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Chapter 1 : Introduction: MURRAY LANDFILL INVESTIGATION

A. Statement of the problem

Murray Landfill operated as the primary refuse site for the City of Springfield, Missouri, from 1968 until 1974 . It was the successor to the Fulbright Landfill, which has been listed as a Hazardous Waste Site for Superfund action by the Environmental Protection Agency's " National Priorities List" of facilities in the nation warranting the highest priority for remedial cleanup action established under the provisions of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA)[1].

In 1980, because the Northwest Wastewater Treatment Plant was severly overloaded due to unexpected increase in population, the City of Springfield began plans to construct another wastewater treatment plant. The proposed location of this plant is on the Southwest corner of the Murray Landfill. A sewer interceptor line is planned to run alongside the Fulbright Landfill to the new plant site which will transmit the overload from the Northwest Plant to the new plant (see Figure 1). This construction has been recommended because it is the most economically feasible alternative, but it is felt that with the problems that could be encountered which involves opening an uncontrolled hazardous waste site and permanent construction on what is probably another uncontrolled hazardous waste site there are deeper concerns than just

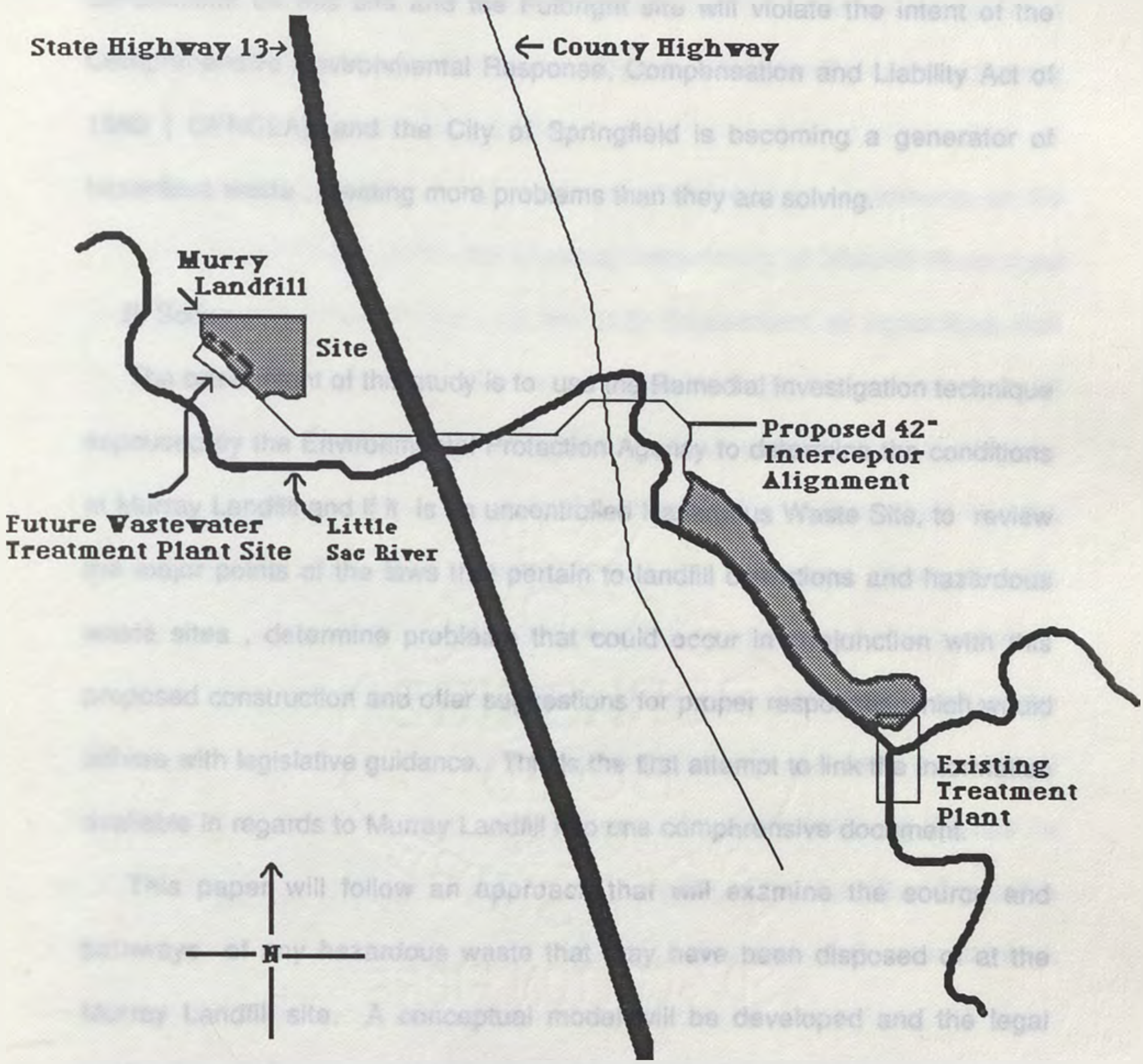


Figure 1: Proposed Northwest Interceptor Sewer

economic alternatives.

This report will show that the proposed location for the new wastewater treatment plant can be defined as an uncontrolled hazardous waste site, that construction on this site and the Fulbright site will violate the intent of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), and the City of Springfield is becoming a generator of hazardous waste , creating more problems than they are solving.

B. Scope

The basic intent of this study is to use the Remedial Investigation technique espoused by the Environmental Protection Agency to determine the conditions at Murray Landfill and if it is an uncontrolled Hazardous Waste Site, to review the major points of the laws that pertain to landfill operations and hazardous waste sites , determine problems that could occur in conjunction with this proposed construction and offer suggestions for proper responses which would adhere with legislative guidance. This is the first attempt to link the information available in regards to Murray Landfill into one comphrensive document.

This paper will follow an approach that will examine the source and pathways of any hazardous waste that may have been disposed of at the Murray Landfill site. A conceptual model will be developed and the legal implications of hazardous waste disposal and management will be examined. Chapter 2 and 3 deal with the source of contaminants by reviewing the history of the operation and the characteristics of the waste. Chapter 4 reviews the site characteristics of Murray Landfill and the surrounding areas in geology , soils,climatology and geography and begins to show the pathways for contaminant transport which are covered in Chapter 5 by focusing on the surface and groundwater movement and other methods of contaminant migration. Chapter 6 deals with legal issues and Chapter 7 gives conclusions and recommendations for future actions.

Information contained in this report was obtained from documents on file with the City of Springfield, the Missouri Department of Natural Resources (MDNR), and references such as the U.S. Department of Agriculture Soil Survey of Greene and Lawrence county , which would be the normal source of such information. No attempt was made to obtain samples from the Murray Landfill, because of pending litigation between the City of Springfield and the manufacturing companies suspected of dumping hazardous waste,although site visits were made for geotechnical/geological mapping and photographs.

This report is considered as a review, compilation and assessment of the technical literature concerning the Murray Landfill as well as original observations of the author. It is designed to aid involved parties in understanding the probable nature of the situation at the landfill and to serve as a guide to work that has been done by other agencies and remedial work that should be done at the site.

Chapter 2: Nature and Extent of the Problem

A. Location

Murray Landfill is located 3 miles North of the City of Springfield, Missouri along State highway 13 and approximately 1/2 mile West along a gravel access road. The legal description locates the landfill in Section 34 of Township 30 North; Range 22 West, State of Missouri. Figure 2 gives a general area location showing its relationship to Springfield and Western Missouri and Figure 3 shows the landfill area on a larger scale. The landfill site is immediately North of Ritter Springs Park. It is bordered on the South side by the Little Sac River. The Northern border is undefined by any natural terrain feature but extends for about one-half mile past the obvious end of landfill operation.

B. History of landfill Operation

The Murray Landfill operated from about 1968 until 1974 as a successor to and partially concurrently with the Springfield Public Works Department Fulbright Landfill. Fulbright is ranked as number 303 (Group 5) of the USEPA's Superfund National Priority List, which is a category that contains waste components of spent cyanide and sulfide solutions [2], and although Murray Landfill is not ranked, several of the parties suspected of being responsible for hazardous waste deposition at the Fulbright site are believed to have used the Murray Landfill for at least one year[3].

Initially , Murray Landfill refuse was accepted in two areas located on the

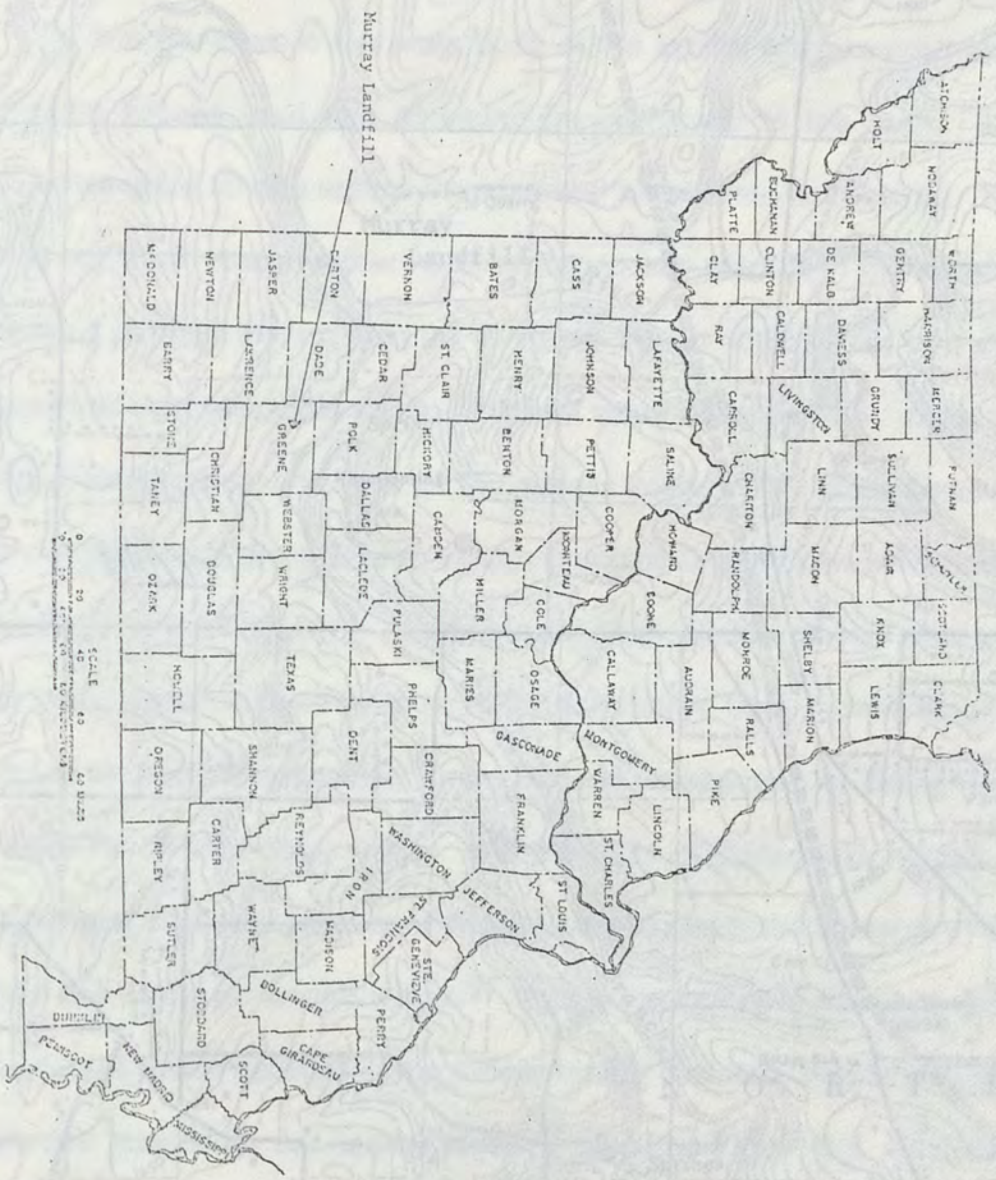


FIGURE 2: INDEX MAP

Figure 3: Site Map

Prepared from USGS Map Ebenezer. MO.(1:24,000)

South side of the Little Sac River near the entrance to the overall facility. (See Figure 4) This area was used until larger trenches could be excavated at the main facility north of the river.

The first trenches in the main body of the landfill were located east of the present access road and extended perpendicular to the river. Additional trenches were formed across the road and futher west as required. No refuse was reported placed either north of the access road or in the drainage area running through the site. Figure 4 shows trench construction and suspected industrial waste disposal areas. The final set of trenches were aligned north of the drainage area and west of the access road.[4] The landfill was operated under provisions of the County Option Dumping Ground Law of Missouri, which was in effective until 1972. Under provisions of this law , it was legal to dispose of toxic metal sludges in a landfill. Statements from former employees of Royal-McBee, a typewriter manufacturer suspected of being the major depositor of hazardous waste, and the City of Springfield indicate that the commonly accepted practice of disposal was to empty the contents of the drums into the body of landfill waste.[5] It is an accepted belief that disposal of drummed waste occured in the former quarry that was originally excavated to provide rock fill for the nearby Highway 13 (See Figure 3). This quarry has been described as roughly a circle of 80 to 100 feet in diameter with a depth of about 12 feet on the South side and 20 feet on the North and located in the Northeast corner of Murray Landfill. The bottom of the quarry was sound,unweathered rock and it was capable of holding water.

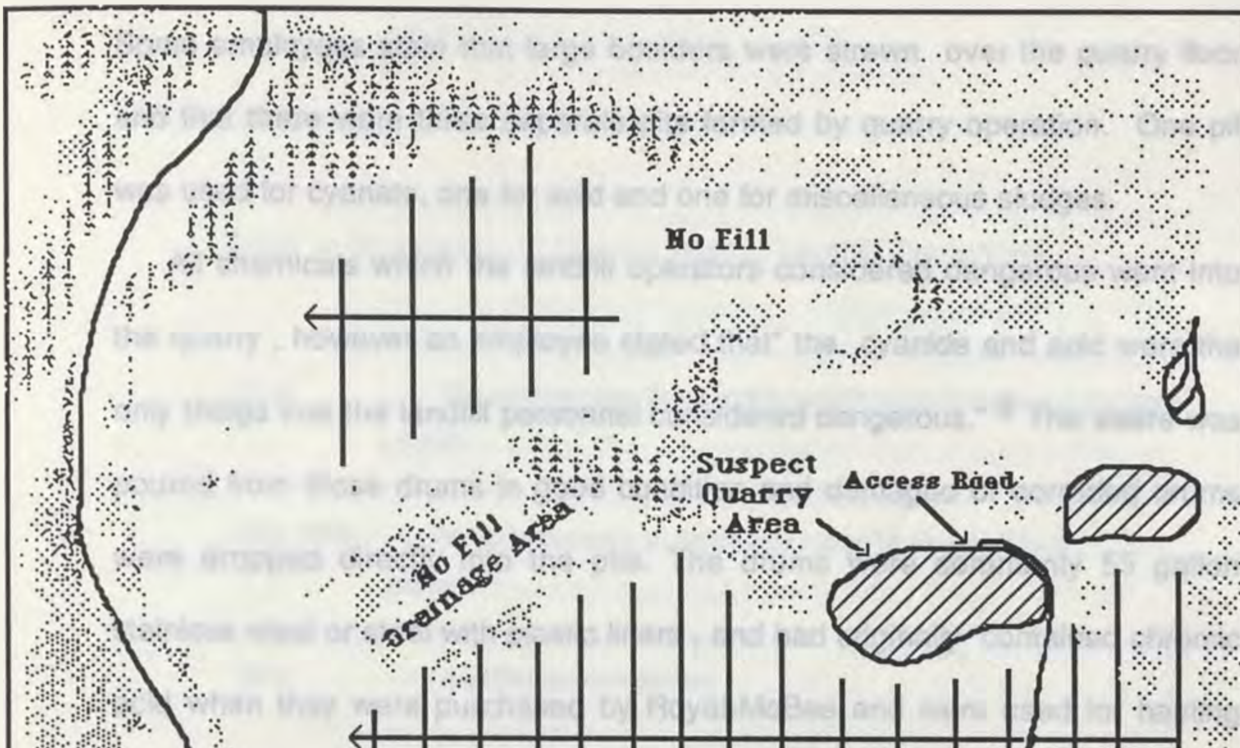


Figure 4: Murray Landfill Map (1:5,000)

Legend

Suspected Industrial Disposal Area

-Trench Alignment & Direction of Construction

-Reported Fire Outbreak Location

N

0' 300' 600'

Some employees state that large boulders were strewn over the quarry floor and that there were three separate pits formed by quarry operation. One pit was used for cyanate, one for acid and one for miscellaneous sludges.

All chemicals which the landfill operators considered dangerous went into the quarry , however an employee stated that" the cyanide and acid were the only things that the landfill personnel considered dangerous." [6] The waste was poured from those drums in good condition and damaged or corroded drums were dropped directly into the pits. The drums were commonly 55 gallon stainless steel or steel with plastic liners , and had originally contained chromic acid when they were purchased by Royal-McBee and were used for hauling waste until they became corroded or excessively damaged. As Royal-McBee plant operators prepared for shut-down in the fall of 1969 they apparantly began dumping more drums into the quarry location instead of pouring them out as was their common practice. Additionally, during this shut-down, a tank containing about 4000 gallons of unconverted sodium cyanide was drained and hauled to Murray Landfill and went into an unidentified quarry pit separate from the customary cyanide pit[7].

The volume of industrial wastes disposed of and the methods of disposal vary from report to report; however, all substantinate that industrial liquid and sludge wastes were disposed of in the quarry area. Waste disposal is believed to have included cyanide, cyanide salt residues of cadmium, zinc,chromium and nickel; sulfuric and hydrochloric acids, chromic acid, TCE , and Stoddard's solvent, sulfur salt, pyrethrum residue, and chlorine chloride[8].

C. Site chronology (Table 1)

Table 1: Chronology of Events, Murray Landfill Operations

1968: Began operation as an active landfill after closure of Fulbright Landfill

1969-1970: Probable dumping of hazardous waste by Royal-McBee and others

1974 Landfill operation ceased

1975: 17 April, Letter to Mr. Robert M. Robinson, MDRN, from Mr. Robert R. Schaefer, City of Springfield, RE: Closing of Old Springfield Landfill which outlines the area of Murray Landfill, gives sampling results and outlines the final closure method.

1979: Study by David L. Coonrod,SMSU student entitled " Metallic Contaminants in Springfield , Missouri's Inactive Northwest Sanitary Landfill" which documented inorganic contamination of copper, chromium and manganese leaching from Fulbright Landfill into the South Dry Sac River and has been credited with initial discovery of Hazardous Waste in the area of the Fulbright Landfill

1980 :

June: USEPA Region VII becomes aware of two disposal sites (Fulbright and Murray Landfills) which were operated by the City of Springfield and which received chemical wastes from firms in the Springfield area. A local television reporter, Mr. Ed Filmer of KYTV is credited with bringing the incident to the attention of USEPA.

August: Division of Environmental Quality, MDNR, Springfield Office files Potential Hazardous Waste Site-Site Inspection Report to EPA.

November: Missouri Governor Joseph Teasdale visits Fulbright Landfill to push for Missouri Hazardous Waste Law.

December: MDNR initial sampling of Fulbright Landfill

1981:

March: EPA develops emergency action plan for Fulbright Landfill which includes groundwater, surface water, and soil sampling to determine contaminant sources(s) and migration pathways.

June: Study by Thomas Aley, Ozark Underground Labatory in regards to Hydrologelogic Mapping of Unincorporated Green County, Missouri to identify areas where sinkhole flooding and serious groundwater contamination could result from land development.

September: MDNR geologist visit Fulbright Landfill to assist in placement of monitoring wells and to evaluate the site.

October: Fulbright Landfill is put on the Interim National Priorities List (NPL).

November: MDNR and the City of Springfield sample monitoring wells at Fulbright Landfill. MDNR samples leachate from the Murray Landfill. EPA develops of list of objectives under Superfund for investigation and remedial actions pertaining to Fulbright and Murray Landfills.

December: Meeting in Springfield between the City of Springfield, USEPA and Missouri Department of Natural Resources on situations at Fulbright and Murray Landfills. City of Springfield agrees to continue monitoring of Fulbright and to expand monitoring to Murray and some private wells.

1982:

January: Letter to Art Groner , MDNR, from Mr. Robert Schaefer , City of Springfield, RE: Potential Hazardous Waste Site , Fulbright and Murray Landfills which is a proposal for monitoring effort to be conducted by the City of Springfield.

April: Site visit and background investigation of Fulbright and Murray landfills by Dr. Harry H. Allen, Environmental Response Team, USEPA, Region VII and suggestions for a monitoring plan .

August: MITRE assessment on Murray Landfill by Lyle Crocker, MDNR

December: Fulbright Landfill was proposed for the NPL in the Federal

Register.

1983:

March: Sampling results published which listed concentrations of hazardous substances above tolerable limits.

April: MDNR proposes covering, grading and stabilizing open leachate areas, ponding areas, and areas of inadequate cover. MDNR also proposes general cleanup and future testing to determine effectiveness of remedial action.

August: Center for Disease Control (CDC) evaluates existing data base with regard to hazard assessment.

The City and its counsultant, Burns and McDonnell, complete an analysis of the Northwest Sewer Interceptor Alignment through the southern edge of Fulbright Landfill and propose the use of a leachate collection system to protect the interceptor. Leachate would be collected and either distributed back on the landfills or treated at the new waste water treatment plant.

September: Letter from Mayor George Scruggs, City of Springfield, to Mr. Fred Lafser, MDNR, requesting reconsideration of placement of the Fulbright and Murray Landfills on the state hazardous waste list.

1984:

April: Memorandum on construction of the Northwest Sewer Interceptor and Treatment Plant through Fulbright and Murray Landfills.

June: Waste Management Program, MDNR approves the proposed excavation and redisposal of the excess soild waste at the Murray and Fulbright Landfills

September: Action Memorandum from David Wagoner, Director, Air and Waste Management Division, Region VII, USEPA to Morris Kay, Regional Administrator, Region VII, requesting authorization for USEPA lead on the Fulbright/Murray Landfill site. This request was approved by Mr. Kay. USEPA gives CH_2M Hill work assignment for preparation of a workplan for PRP(s) to conduct the Remedial Investigation and Feasibility Study under the supervision of the EPA.

1985:

February: USEPA approves the " Leachate and Waste Management Plan for Northwest Interceptor and Wastewater Treatment Plant" .

March: CH_2M Hill completes their Final Work Plan (PRP Implementation) RI/FS Fulbright and Murray Landfill

D. Probable Operating procedures

It is necessary to reconstruct the basic characteristics of original waste management of the site and determine the effect of such practices on any effort to clean-up or remediate the site. It is recognized that an effective site remediation at the Murray Landfill must differentiate between any groundwater degradation associated with leachate stemming from municipal refuse and hazardous constitutents related to disposal from the Royal-McBee operation and others As far as has been determined, operations at the Murray Landfill did not result in records of the time and location of placement (vertical and/or horizontal) of any waste. The only apparent record is obtained from former employees of Royal-McBee and the City of Springfield and in the documented interviews conducted by Massey and Roberts questions arise about the location and separation of hazardous waste.

1. Nature of Land burial operation

a. Probable design characteristics

The Murray Landfill apparently was designed and operated to take full advantage of several governing site characteristics:

o. An elevated flood plain comprised of potential cover material;

o. The North-bounding bedrock hillside with its thin residual soil cover;

o. The flood plain piezometric surface as controlled by flow stages of the Little Sac River.

With these resources and constraints it is highly probable that the landfill operators operated on a concept of creating landfill volume through the excavation of flood plain soils, while leaving a natural flood protection berm of unexcavated soil. If this was the case, the landfill operation, beginning as indicated on the September, 1970 photograph [9], began at the Eastern boundary of the site and moved Westward in the flood plain. This operation would have consumed excavated flood plain soils as daily and final cover , while relying on the developed volume of waste excavation for continued waste placement. Given these conditions, it is likely that the landfill base was simply developed by excavating downward to a depth determined by seasonally high groundwater and some minimal waste to groundwater separation thickness. If this was the case, a possible profile through the landfill and the Little Sac River would have been as shown on Figure 5 . In this figure note the following elements:

o. piezometric surface

o. natural flood plain dike

o. lower most landfill pocket

o. first landfill bench

o. second landfill bench

This conceptual cross-section illustrates that the groundwater level may be very close to the waste and in fact, waste may penetrate the piezometric surface. If the seasonal groundwater level was low , when the area was excavated for waste placement , as in the summer months, it is very probable that waste deposits exist below the water table.

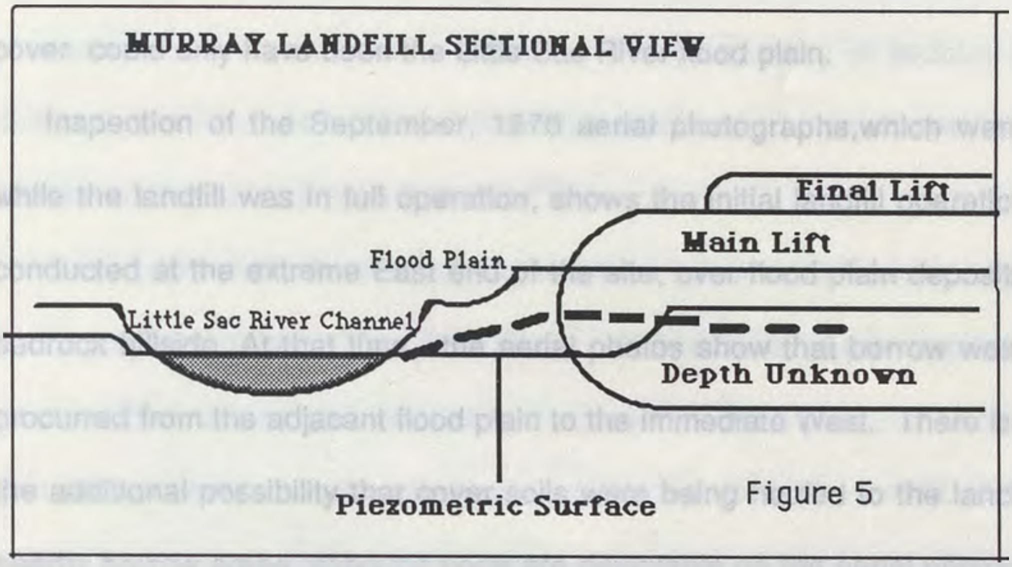


Figure 5

b. Natural Base materials

It is probable that the natural base of the landfill occurs in either of two materials, limestone bedrock or alluvial plain. The Northern-most portion is apparently underlain by limestone bedrock. This rock base would abruptly meet various landfill lifts that were founded on the second base material, which is probably a excavation-graded surface lying below the original flood plain. In its finished state the landfill offers no direct evidence of either condition. There is no reason to suppose that any special provision were used in preparing the landfill base other than this type of excavation and grading of available flood plain materials. It is suspected that the residual soil is probably no more than 3 to 5 feet in thickness. This assessment is also supported by the current presence of a 1-acre cemetary remaining as elevated ground, located about 650 feet West of the common Section corner and about 75 feet South of the Section 26/34 boundary line. The only substantial borrow source for landfill cover could only have been the Little Sac River flood plain.

Inspection of the September, 1970 aerial photographs,which were taken while the landfill was in full operation, shows the initial landfill operation being conducted at the extreme East end of the site, over flood plain deposits and a bedrock hillside. At that time, the aerial photos show that borrow was being procurred from the adjacent flood plain to the immediate West. There is always the additional possibility that cover soils were being hauled to the landfill from nearby borrow areas, although none are detectable on the aerial photographs. From inspection of the numerous open exploration pits that had been dug buy the City for monitoring the construction effort, it appears that there is no evidence of an appreciable thickness of daily cover in the exposed waste mass (to depths of about 12 feet). Final cover is of minimal thickness , but is sufficient to support the natural grass cover found at the landfill. The final contours of the landfill cover were designed to ensure that drainage is not a problem . The area outlined for primary drainage is on the Western edge and serves this purpose very well (See Figure 4).

The absence of any restrictions on dumping during the time period of operation of Murray Landfill implies hazardous waste could be spread throughout the landfill rather than the quarry as is presumed in the Interceptor Sewer contract. However, common sense state of art management would have called for segregration into one area. There has to be some search conducted to determine if hazardous waste was indeed controlled by area. The idea that the quarry was the primary site and that three separate pits existed for disposal of waste has to be accepted. However, a large quantity of sodium cyanide dumped at the close of Royal-McBee operations is unlocated and only mentioned in one employee interview[10].

The portion of the landfill property that was converted into waste disposal is the floodplain of the Little Sac River. Not only is there relatively high groundwater , but an additional hazard arises from flood potential fluctations in groundwater level and possible flooding of the first lift of the landfill. Based on limited information available, it is possible that the soil lining of the facility could be quite thin above groundwater due to the requirement to borrow from the natural soil liner to create a natural soil cover for waste. This increases the potential of leachate migration to groundwater, particularly during seasonal increases in groundwater elevation.

The speculation on location of hazardous waste disposal , the lack of restictive operating procedures or guidelines for control of hazardous waste, and the probable operating conditions present at the site give credence to considering Murray Landfill as an uncontrolled hazardous waste site.

Chapter 3: Waste Characteristics

A. Hazardous Substances

1. Waste Characterization:

In April 1975, when the City of Springfield closed Murray Landfill , Mr. Robert Schaefer sent a report to the Solid Waste Management Division of the MDNR covering the closure methods used. This report stated that all areas had been filled with at least two (2) feet of cover, final contours had been designed to insure that drainage was not a problem and that all excavated areas would be seeded with perennial grass. Additionally, the City tested four points along the river adjacent to the landfill for Biochemical Oxygen Demand (BOD), Suspended Solids (SS), Chemical Oxygen Demand (COD), Total Organic Carbon (TOC), PH, and fecal coliforms. None of these tests indicated any abnormal values and the City made the assumption that the Little Sac was not being polluted by any landfill leachate and the closure method employed was sufficient.[11] A 1979 study by a college student disclosed copper, chromium and manganese contamination leaching from Fulbright landfill[12] and the subsequent publicity resulted in the 1980 study conducted by Massey and Roberts.

a. Waste Types

The hazardous wastes disposed of at the Murray landfill were the result of the manufacture of typewriters and electrical parts. Both organic and inorganic contaminants have been detected at the site. In the report submitted by Massey and Roberts they list a variety of hazardous wastes that are found at the site . Additionally , in an October 1984 letter from Ms. Alice Fuerst, EPA Region VII to Mr. Lloyd Shadrick, Natkin and Company, a potential contractor for construction on Murray Landfill, several other suspected hazardous substances are mentioned[13] and are included in Table 2 .

TABLE 2: WASTES AT MURRAY LANDFILL

1. aqueous solutions of cyanide and cyanide salts;
2. plating residue containing cadimum , zinc , chromium , and nickel;
3. spent sulphuric and hydrochloric acids;
4. spent chromic acids;
5. acidic chrome strippers and steel strippers;
6. stoddard solvent and TCE;
7. a sulfur salt used in a molten salt bath;
8. plater paint;
9. waste oil.
10. Pyrethum residue
11. Choline chloride bottom still residue
12. Phosphates
13. Trichloroethylene

b. Waste Composition

At the request of the MDNR Waste Management program, leachate sampling was conducted at the Murray Landfill in November 1981. The results of this sampling , taken from a leachate pool on Murray , indicated concentrations higher than acceptable limits for the National Interim primary drinking water standards for Nitrate, Chloride, Barium and Silver.[14] Upon receipt of this report, and after meeting with representatives of the Environmental Protection Agency , the City responded with their own proposal for monitoring to determine if either landfill warranted futher action. Their program provided for sampling to occur starting in July 1982 and continuing until December 1982 , at which time they would meet with EPA and decide if futher work was necessary.[15] Table 3 is a listing of the composition of wastes discovered at the Murray Landfill, as well as the maximum concentration of

TABLE 3: Composition of Wastes

FORM	CONCENTRATION (mg/l)	DATE
BOD	7.43	12/82
SS	37.43	12/82
TOC	55.83	7/82
NH3-N	41.92	9/82
Nitrate	62.25	10/82
TCE	0.005	10/82
CR	<0.05	All Dates
CN	<0.10	10/82-12/82
CD	<0.05	All Dates
PB	<0.30	7/82-8/82
AS	<0.10	All Dates
BA	11.40	9/82
AG	0.10	7/82
HG	<0.001	All Dates

each waste found during environmental monitoring by the City of Springfield and the date that this maximum concentration was observed.This sampling was performed during the period of July to December 1982. Figure 6 shows the location of sampling points relative to the Murray Landfill. The City discontinued their sampling even though the concentrations of Nitrates and Barium exceeded the recommended level for drinking water and the concentrations of Cynanide and Arsenic exceeded the recommended level for aquatic life.[16]

The Division of Environmental Quality, MDNR conducted sampling of Murray Landfill on December 1, 1982 and March 15, 1983. The results of this sampling are reproduced below in Tables 4 and 5. The location of the sampling points are shown on Figure 7.

c. Waste Characteristics:

Arsenic is known to be a cumulative carcinogenic and to have cardiovascular effects. Cyanides have been found to cause weakness, headaches, confusion, nausea, vomiting , eye and skin irritation, and slow , gasping respiration. Cadmium is a carcenogenic and may cause kidney damage, arteriosclerosis,nausea, diarrhea, headaches, muscle aches, irritation of the respiratory tract and weight loss. Chromium has been found to cause dizziness, abdominal pains and dermatitis and is a known carcinogenic. Copper has an emetic effect and may cause liver damage. Lead is cumulative and may cause plumbism and nephritis.

Trichloroethylene may cause irritation of eyes, nose, and throat, dermatitis, headaches, dizziness, tremors, nausea,

TABLE 4: December 1, 1982 Sampling

COMPOUND	CONCENTRATION (ug/l)		LOCATION	
	Maximum	Above EPA Limit	Maximum	Above Limit
Arsenic	14.0	No	3	
Cadimum	2.0	No	2	
Chromium	21.0	No	2	
Copper	18.0	Yes	2	2,3&4
Lead	74.0	Yes	2	2
Mercury	<0.5*	Yes	All	All
Nickel	130.0	No	2	
Zinc	260.0	No	2	
Cyanide(mg/l)	0.019**	Yes	2	1,2 &4

* Exceeds the recommended criteria for aquatic life

TABLE 5: March 15, 1983 MDNR

Compound	Concentration (ug/l)	Location
trans-1,2-Dichloroethene	15	Point 5
Benzene	11	Point 7
Chlorobenzene	26	Point 7
Benzene	18	Point 6
Ethylbenzene	37	Point 6
Toluene	28	Point 6

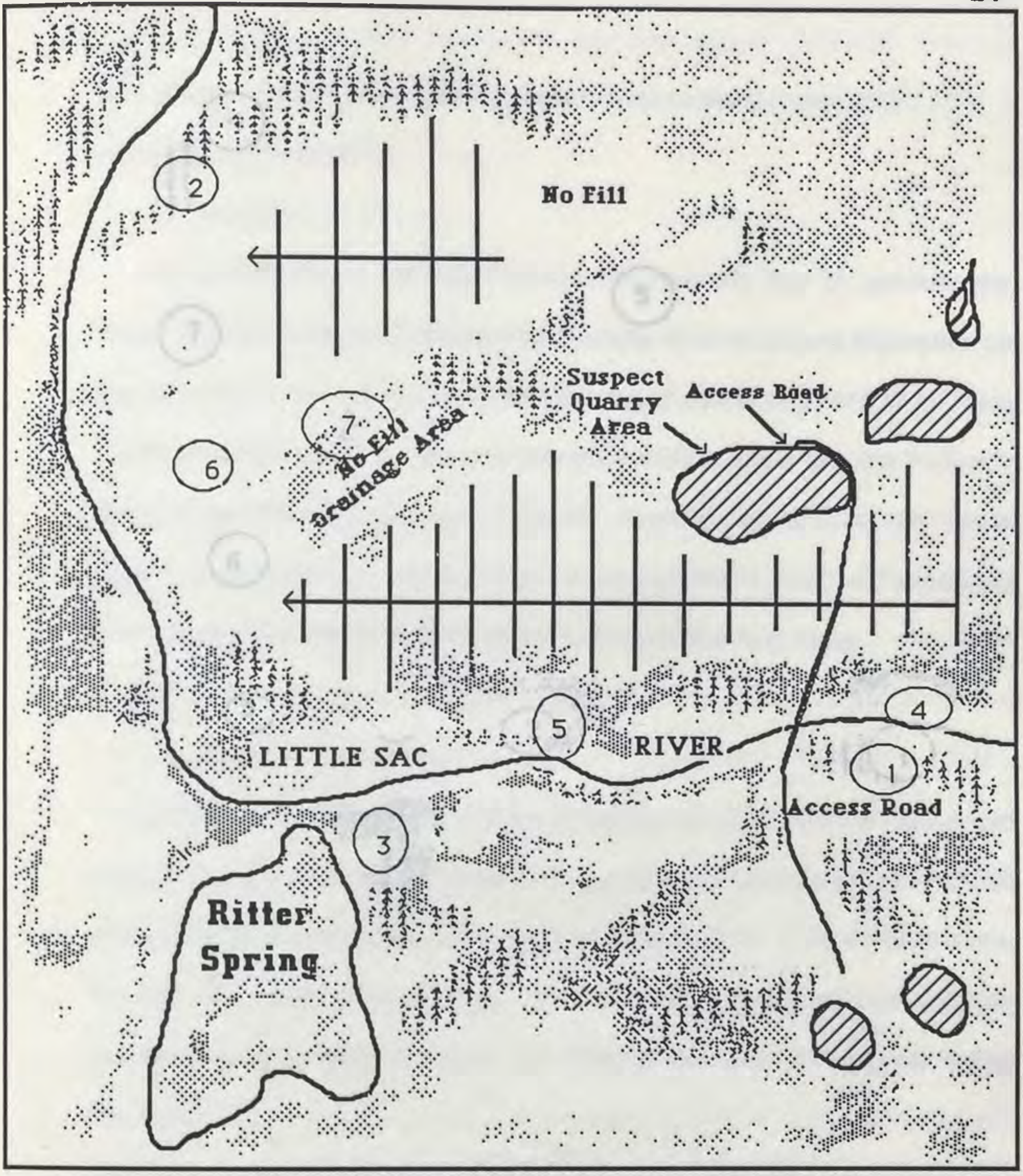
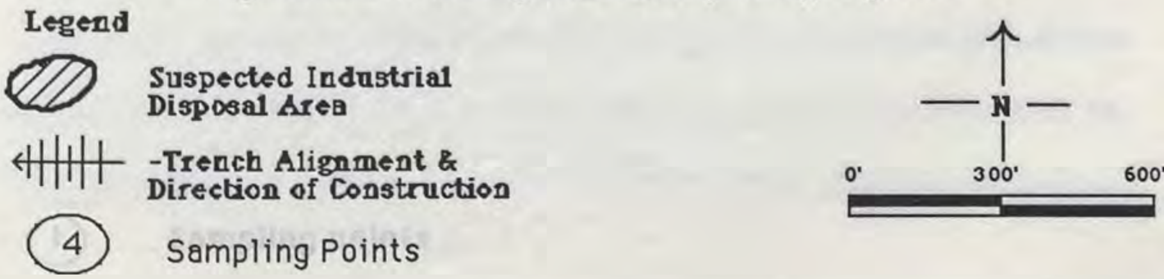


Figure 6: Monitoring Points, City of Springfield



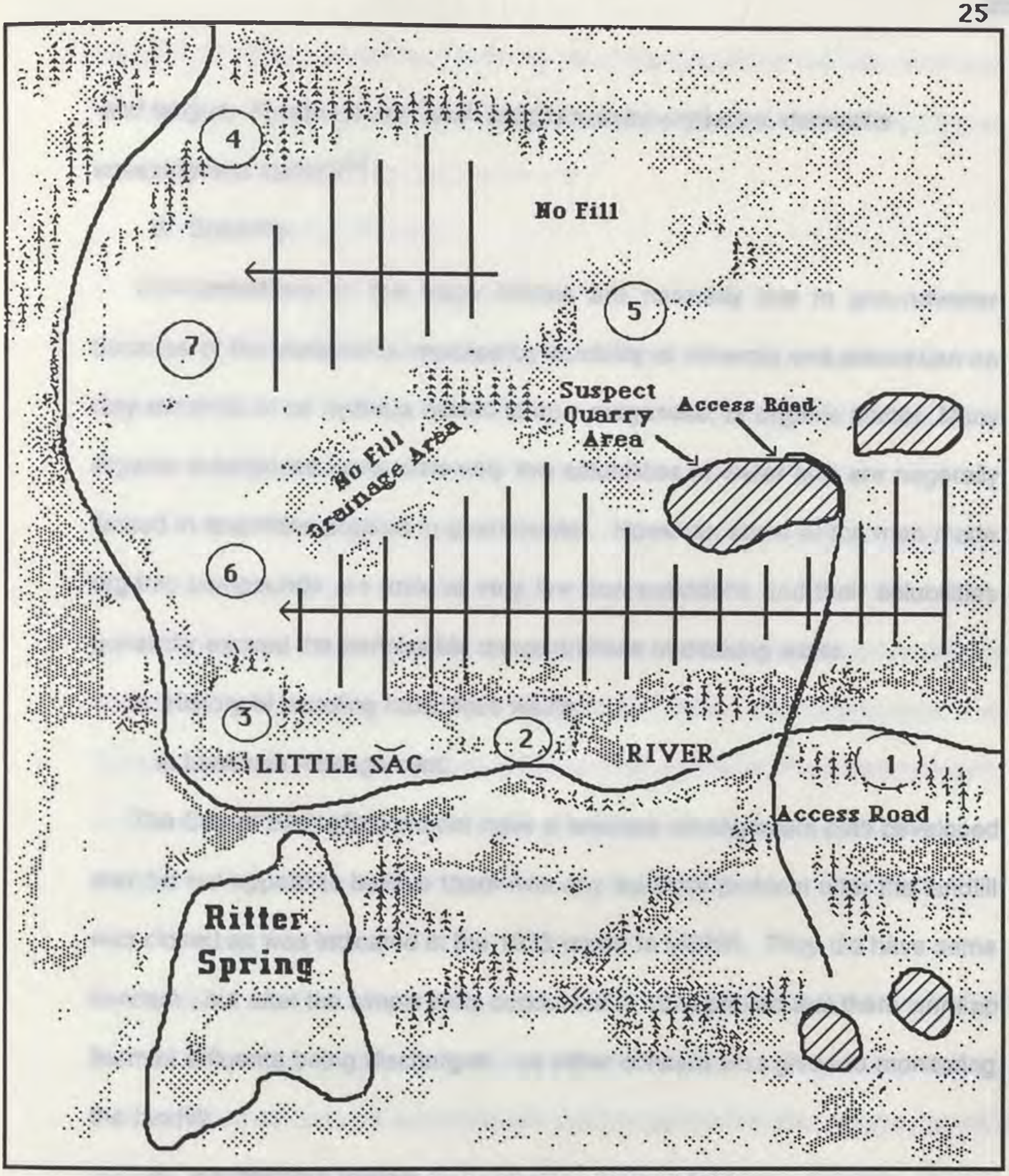
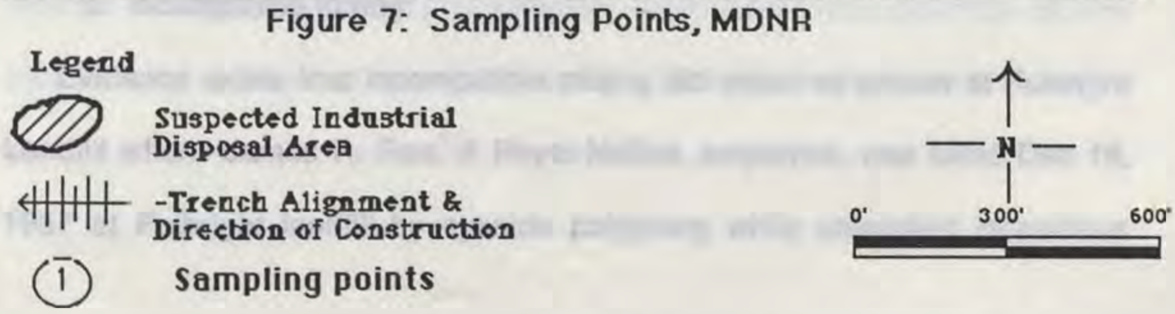


Figure 7: Sampling Points, MDNR



and fatigue. Pyrethrum has been found to cause erythema, dermatitis , sneezing and asthma[17].

d. Solubility:

Concentrations of the trace metals are normally low in groundwater becaues of the constraints imposed by solubility of minerals and adsorption on clay minerals or on hydrous oxides of iron ,maganese, or organic matter. Many organic substances have extremely low solubilities in water and are negerally limited in quantities present in groundwater. However, some of the man-made organic compounds are toxic at very low concentrations and their solubilities generally exceed the permissible concentrations in drinking water.

2. History of handling hazardous waste

a. Leachate management:

The City of Springfield did not have a leachate management plan developed and did not appear to believe there was any leachate problem after the landfill was closed as was indicated in the 1975 report to MDNR. They did have some concern , but after the simple tests conducted in 1975 proved that there were no harmful effluents being discharged , no other concern was given to monitoring the landfill.

b. Incompatible mixing:

Evidence exists that incompatible mixing did occur as shown at Fulbright Landfill when James R. Rea, A Royal-McBee employee, was killed Dec 18, 1967 at Fulbright landfill by cyanide poisoning while unloading hazardous waste. Eyewitness accounts states that Rea was unloading cyanide salts and mild acid solutions which mixed and caused a cyanide gas cloud, resulting in his accidental death[18].

B. Probable Contributors

1. Royal-McBee

Royal-McBee was the most significant hazardous waste generator who disposed of waste at Fulbright. They disposed of between 1200 and 2600 drums of hazardous waste during their operations from 1959 to 1970. No records were kept so these are estimates. However, Fulbright was closed in 1968, so some of this hazardous waste was dumped in Murray. This waste consisted of toxic cyanide, cadimum, and chromium as well as less hazardous chemicals including cyanate , zinc, nickel, various acids , trichloroethylene, and various solvents. Royal-McBee dumped their waste on their own property 1959-1963 at 2401 E. Sunshine St. (now owned by General Electric) , at Fulbright 1963-1969 then at Little Sac River Landfill (Murray) 1969- 1970 [19].

2. Syntex (Hoffman-Taft)

Syntex (Hoffman-Taft), disposed of various wastes at Fulbright that included filtercake containing ammonium chloride, potassium chloride , sodium chloride from dl-Lactone synthesis of calcium pentaphenate, dl-Lactone still residue containing carbon and nitrogen compounds and possibly choline chloride and a chemical containing iodine. Syntex also disposed of a limited amount of pyrethrum residue [20].

3. Dayco and others

Dayco, a local tire manufacturing firm has been identified as dumping quantities of naptha and rubber waste and other unnamed companies have dumped paint, paint thinner and turpentine [21].

C. Indicators of Contamination and Contaminant Transport

1. Coonrod Report.

The first evidence of possible contamination near the Fulbright Landfill was found in an unpublished report by David L.Coonrod, a student at Southwestern Missouri State University in 1979. His report showed that significant amounts of of copper, chromium and manganese were leaching into the Little Sac River from Fulbright Landfill and were being transported downstream to the area of the Murray Landfill. This report inspired local television reporters to notify the Environmental Protection Agency of the possible problems and instigated all futher actions.

2. Sutton Thesis:

Virginia A. Sutton , a graduate student at Southwest Missouri Sate University in her thesis entitled " Toxic Metal Concentrations and Distribution in soils of Four Abandoned Landfill Sites, Springfield , Missouri " examined several landfills for cadimum, nickel, zinc, lead, copper and chromium. According to Sutton's analyses performed upon grab samples obtained at the Murray Landfill, no excessive values of lead ,cadimum or nickel were found . Probable excessive values of chromium and copper were found (Figures 8 and 9) , with maximum concentrations of 132 mg/l and 86 mg/l respectively. The National

Interim Primary and Secondary Drinking Water Regulations show the standards established by EPA. (Table 6)[22] .

3. MDNR Monitoring Results

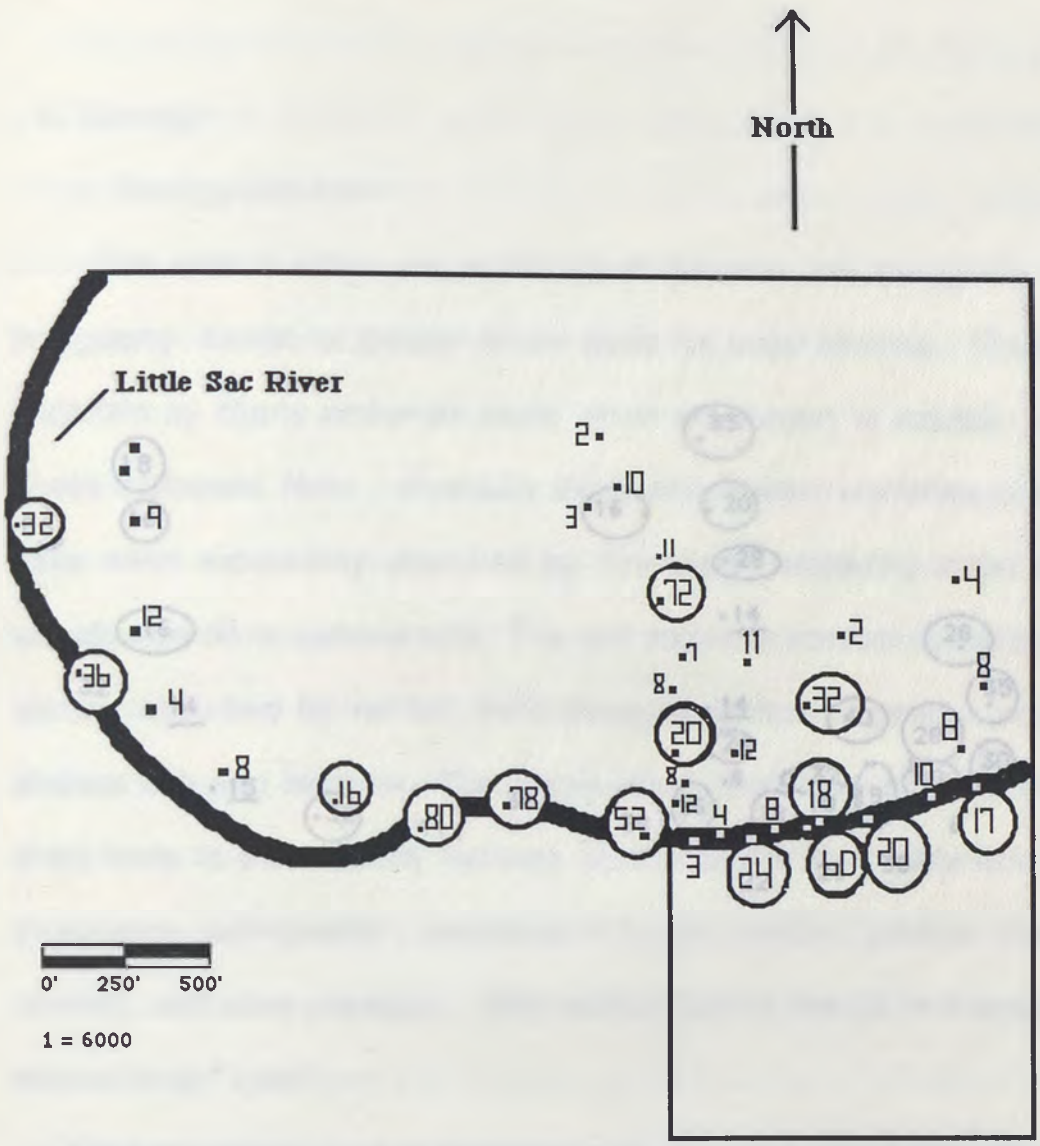
The samples taken at point 1 on figure 7 indicate that concentrations of mercury and cyanide exist in the Little Sac river that exceed the recommended criteria for aquatic life, so it is evident that some hazardous waste is being transported by the surface water system even before the major river reaches the landfill. Additionally , samples taken at point 1 indicate a concentration of trans-1,2 - Dichloroethene. On the landfill itself, excessive concentrations of copper and mercury exist at points 2, 3, and 4 and lead and cyanide in concentrations harmful to aquatic life are present at point 2, and cyanide by itself at point 3. Benzene is present at points 6 and 7 , with chlorobenzene at point 6 and ethylbenzene and toluene present at point 7 . The presence of the compounds on the landfill gives rise to concern that they may be transmiitted into the surface water or groundwater system present in the area. The natural characteristics of the site will indicate the probability of contaminant migration.

TABLE 6

PERTINENT CONSTITUTENTS FROM THE NATIONAL INTERIM PRIMARY AND SECONDARY DRINKING WATER REGULATIONS

Primary		Secondary	
Constituent	Concentration (mg/l)	Constituent	Concentration (mg/l)
Arsenic	0.05	Chloride	250.0
Barium	1.0	Copper	1.0
Cadmium	0.010	Iron	0.3
Chromium	0.05	Manganese	0.05
Lead	0.05	Sulfate	250.0
Mercury	0.002	Zinc	5.0
Nitrate as N	10.0		
Selenium	0.01		
Silver	0.05		
Fluoride	1.4 to 2.4 (depending on average air temperature)		
Endrin	0.0002		
Lindane	0.004		
Methoxychlor	0.01		
Toxaphene	0.005		
2,4-D	0.1		
2,4,5-TP Silvex	0.01		

40 CFR 264.95 page 412.



NE 1/4, sec. 34, T 3 ON, R 22W

MURRAY LANDFILL

Figure 8: Sutton Thesis, Chromium Concentrations

ANOMALOUS VALUES: Possible____ Probable

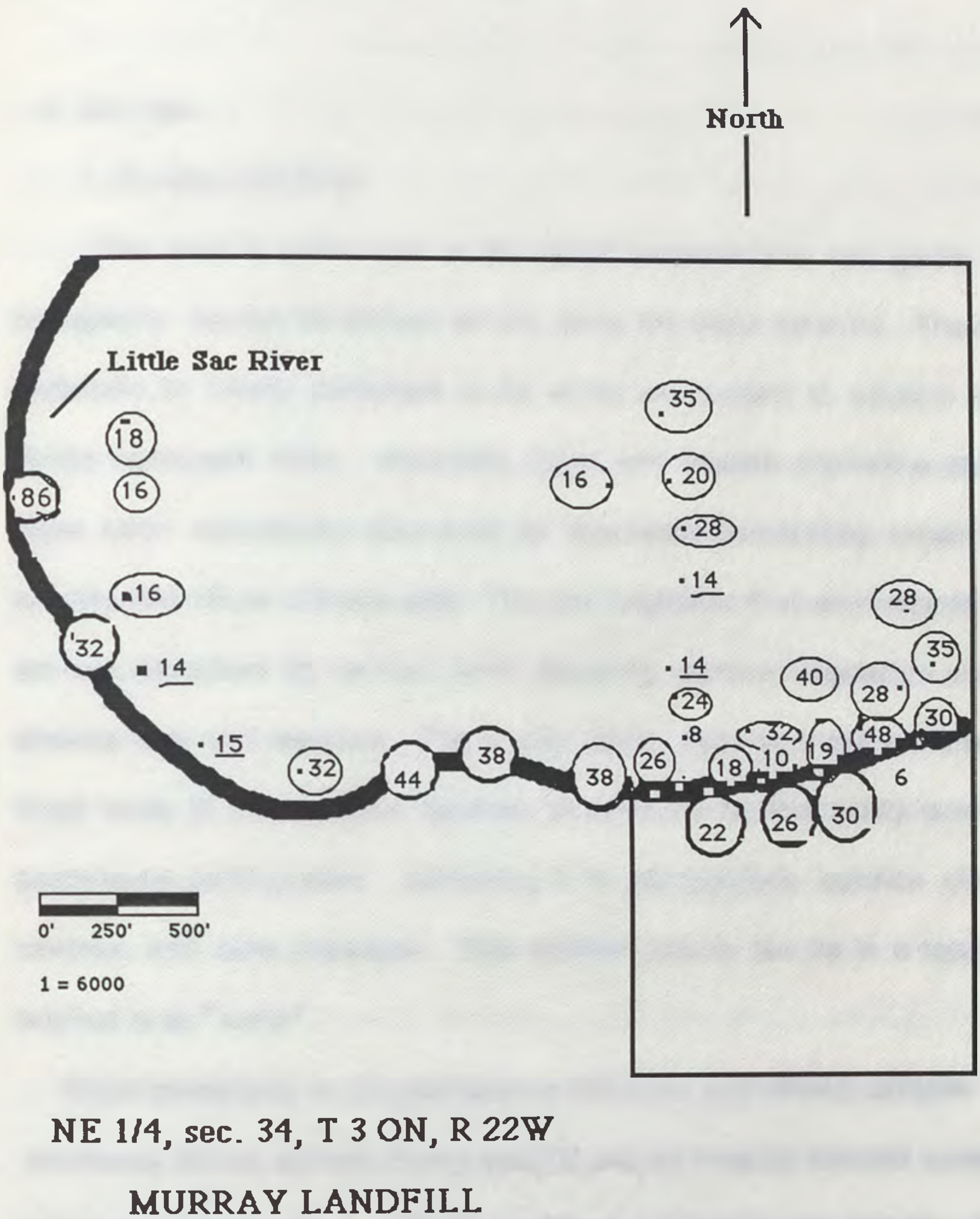


Figure 9; Sampling Points , Sutton Thesis, Copper Concentrations

ANOMALOUS VALUES: Possible____ Probable

Chapter 4 : SITE CHARACTERISTICS

A. Geology

1. Geology and Soils :

This area is within one of the Ozark plateaus and has gently rolling topography except for steeper terrain along the major streams. The area is underlain by cherty carbonate rocks which are subject to solution activity. These carbonate rocks , especially those with coarser crystalline structure, have been extensively dissolved by downward-percolating water that is actually very dilute carbonic acid. This acid originates from atmospheric carbon dioxide absorbed by rainfall, from decaying surface vegetation,and from shaless with acid leachate. The cracks, joints, fissures bedding planes, and chert beds in the bedrock facilitate penetration by the mildly acid water percolating underground , permitting it to cut crevices, solution channels, caverns, and cave passages. This solution activity results in a topography referred to as " karst ".

Karst topography is characterized by sinkholes and related collapse structures, caves, springs, losing streams and an irregular bedrock surface of " cutter' and " pinnacles ". These cutters and pinnacles are solution crevices and isolated pillars of rock, commonly marked by 10 to 15 feet of relief in the bedrock surface. Approximately 20 to 30 percent of Greene county drains into sinkholes and almost all of the county is underlain by some feature of the Karst topography[23].

2. Bedrock Structure (See Figure 10)

The physiographic province of primary concern in this area is the Springfield plateau, which is mainly an undulating to rolling plain. It is on Mississipian rocks and on relatively small portions of Pennsylvanian rocks. Bedrock is present at varying depths . It consists of sedimentary rock, mostly limestone, dolomite, sandstone, and shale. Limestone, some of which is very cherty, is predominant. Faults are common.

The youngest rocks in the area underlie the Basehor-Bolivar association. These rocks are of Pennsylvanian age. They are part of the Cherokee Group, a coarse grained to fine grained sandstone that has some conglomerate at the base that is typical of the Warner formation. The formations are comparatively thin and exposed in less than 2 % of the area. Cambrian rocks , the oldest formations in the area are not exposed. In most places , however, high yields of water can be obtained from the Eminence and Potosi formations.

Rocks of Ordovician age overlie the Cambrian rocks. The Cotter formation and most of the Jefferson City formation are very similiar in lithology.They both consist predominantly of cherty limestone. The Cotter formation includes lenses and locally persistant beds of sandstone. The Roubidoux formation, consisting of sandstone, dolomitic sandstone and cherty dolomite, underlies the Jeffreson City formation. This is a major source of water. Higher yields of good water can be obtained from the Gasconade Dolomite especially the lower very cherty part or from the Gunter sandstone.

GENERALIZED SECTION OF GEOLOGIC FORMATIONS IN THE SPRINGFIELD AREA*

SYSTEM	SERIES	GROUP	FORMATION	THICKNESS (FT.)	LITHOLOGY		HYDROLOGIC CHARACTERISTICS
QUATERNARY	Pleistocene and Recent		RESIDUUM AND ALLUVIUM	5 - 30	*Residuum* - silt, clay, soil, chert fragments. *Alluvium* - silt, clay, fine grained sand.		Not important as an aquifer in the study area.
PENNSYLVANIAN	Desmoinesian		WARNER FORMATION	0 - 95	Sandstone and conglomerate, very irregular in distribution and thickness.		Not important as an aquifer in the study area.
MISSISSIPPIAN	Meramecian		WARSAW FORMATION	40 - 60	Fine to coarsely crystalline, slightly cherty limestone.		Not important as an aquifer in the study area.
	Osagean		BURLINGTON-KEOKUK LIMESTONE	155 - 270	Medium to coarsely crystalline limestone with nodular and bedded chert.	Minor Aquifer	This interval yields small to moderate (1 - 20 gpm) quantities of water to wells in the study area. Springs are common in this horizon. Water draining from this aquifer maintains dry weather flow of streams. Water is of a calcium-bicarbonate type.
			ELSEY FORMATION	25 - 75	Finely crystalline limestone with abundant nodular and massively bedded chert. In the Springfield area the Elsey Formation rests on the Pierson Formation and is overlain by the Burlington-Keokuk Limestone.		
			REEDS SPRING FORMATION	0 - 125	Gray, grayish green and red limestone, and green and red calcareous shale. To the south and southwest of the Springfield area the Reeds Spring Formation intervenes between the Pierson and the Elsey.		
			PIERSON FORMATION	5 - 90	*Upper* - Cherty limestone and dolomitic limestone. *Lower* - Massively bedded brown dolomite.		
	Kinderhookian	Chouteau	NORTHVIEW FORMATION	5 - 80	Brownish siltstone and blue or bluish green shale.	Confining Layer	Upper confining layer for major aquifer. Retards downward movement of water from minor (limestone) aquifer to major (dolomite) aquifer.
			COMPTON FORMATION	2 - 30	Finely crystalline to sublithographic limestone.		Not important as an aquifer in the study area.
			BACHELOR FORMATION	0 - 5	Greenish, quartzose sandstone, with calcareous cement.		
DEVONIAN	Upper		CHATTANOOGA SHALE	0 - 5	Dark gray to black fissile shale.		Thin isolated occurrences recorded in well records. Not hydrologically significant.
			SYLAMORE SANDSTONE	0 - 5	Sandstone with numerous black phosphatic nodules.		
ORDOVICIAN	Canadian		COTTER DOLOMITE	55 - 355	Dolomite, cherty dolomite, bedded chert, and quartz sandstone.	Major Aquifer	This sequence acts as a hydrologic unit in this area. Wells open to the total thickness have been pumped at rates of 2,000 gpm. Water from this aquifer is a calcium magnesium bicarbonate type.
			JEFFERSON CITY DOLOMITE	180 - 250			
			ROUBIDOUX FORMATION	140 - 250			
			UPPER GASCONADE DOLOMITE	40 - 100			
			LOWER GASCONADE DOLOMITE	235 - 320			
			GUNTER SANDSTONE MEMBER	25 - 50			
CAMBRIAN	Upper		EMINENCE DOLOMITE	260 - 350	Dolomite with small amounts of cherty dolomite.		
			POTOSI DOLOMITE	20 - 120			
		Elvins	DERBY - DOERUN DOLOMITE	85 - 105	Dolomite interbedded with thin bedded siltstone and shale.	Confining Layer	Probably a confining layer for the overlying dolomite aquifer.
			DAVIS FORMATION	140 - 155	Shale, siltstone, fine-grained sandstone, dolomite and limestone conglomerate.		
			BONNETERRE FORMATION	185 - 260	Medium to fine grained, medium bedded dolomite.		Probably not important as an aquifer in the study area.
			LAMOTTE SANDSTONE	180	Quartzose sandstone.		
PRECAMBRIAN					Igneous rocks.		Top of Precambrian is about 2000' below land surface. Does not yield water.

*The stratigraphic nomenclature used in this report is that of the Missouri Division of Geology and Land Survey and differs somewhat from the current usage of the U.S. Geological Survey.

FIGURE 10: BEDROCK STRUCTURE (Page 21, Water Resources Report # 34 , 1978)

Between the Pennsylvanian and Ordovician rocks are Mississippian rocks, which have greater total thickness and by far the greatest distribution in the area. The Mississippian rocks are predominantly cherty limestone, but the chert content varies from minor amounts in the Burlington-Keokuk Formation to abundant amounts in the Elsey formation. Shale and sandstone dominate the Northview formation, shale and sandstone members dominate the unconforming Carterville Formation and sinkholes and caves are most commonly developed in the Burlington-Keokuk and Pierson Formations.

Unconsolidated surficial deposits include residiuum, loess, colluvium and alluvium. Soil is formed in these deposits. Residuum and colluvium are dominant except for relatively small areas that have a loess cap or alluvium[24].

B. Soils

1. Dominant Soil Types:

The primary soil types related to the Murray Landfill are Huntington Silt Loams (55), Pearidge Silt Loam (21B), Goss Cherty Silt Loam (43D) and Gasconade-Rock Outcrop Complex (83D). A review of these types looking at their characteristics, usage, and eroision potential is essential in making decisions on appropriate remedial alternatives. The soils map identifies the sites of Murray and Fulbright Landfills with a special map units called Orthents (943), which indicates a manmade soil, consisting mainly of landfill refuse. Another area, which is the site of an abandoned quarry, is identified as Pits and

Dumps (941) and also has a special map unit developed for manmade soils. (See Figure 11) The erosion estimates come from the Universal Erosion equation taken from Chow[25] which is:

A= RKLSCP

A= Average annual soil loss in tons/acre

R= Rainfall factor, = 300

K= Erosion factor, different for each type of soil,taken from the USDA soil survey

LS= length slope , 2.8

C= 1

P=1

2. Huntington silt loam (55)

a. Permeability:

This soil is moderately permeable, surface runoff is medium, and available water capacity is very high. An apparent water table is at a depth of 4 to 6 feet from December to April in most years.

b. Common usage:

Most areas of this soil are in cropland. Some areas are in pastureland or hayland. A few isolated and limited areas are in woodland. Occasional flooding from December to May is a major concern of management. It is generally not suited to building site development or onsite waste disposal because of this occasional flooding.

FIGURE 11: Soils Map (Reproduced from Plate 22, Soil Survey of Greene and Lawrence Counties,USDA)

c. Erosion

K= .028 , A = 268.8 tons/acre

3. Pearidge Silt Loam (21 B)

a. Permeability

This soil is moderately permeable, runoff is medium to slow, and available water capacity is high. Shrink-swell potential in the lower part of the subsoil is moderate.

b. Common Usage

Most areas of this soil are in cropland and pastureland. A few areas are in woodlands. Considerable acreage is used for dwellings and other urban development. This soil is suited to cropland, but moderate susceptibility to erosion is a concern of management. Minimum tillage and careful management effectively control erosion in most areas if small grain and meadow are dominant crops. If row crops are dominant in the cropping sequence, grassed waterways and field terraces are commonly needed.

c. Erosion: K = 0.37 ; A = 310.8 tons/acre

4. Goss cherty silt loam (43 D)

a. Permeability:

The Goss soil is moderately permeable. Runoff is rapid, and available water capicity is low. The shrink-swell potential is moderate.

b. Common Usage:

Most areas of this soil are in pastureland,hayland,and woodland. This soil is suited to building site development and to some onsite waste disposal systems.

Terraces, grassed waterways , minimum tillage, and contour cultivation help to control erosion and retard runoff.

c. Erosion: K = .024; A=201.6 tons/acre

5. Gasconade-Rock outcrop complex (83 D)

a. Permeability

Permeability is moderately slow and runoff is rapid. Hard bedrock at a depth of less than 20 inches results in a very low available water capacity and a shallow root zone. Shrink-swell potential is moderate.

b. Common usage

Most areas of this complex are in native grasses and legume pastureland with isolated glades of woodlands. Areas of this complex are generally not suited to building site development and onsite waste disposal. Major limitations are the shallow depth to bedrock, outcrops of rock, and stones and small coarse fragments of chert and limestone on the surface.

c. Erosion K=0.20 ; A = 168 tons/acre

6. Pits and Dumps (941)

a. Permeability

This unit consists of open excavations or pits from which limestone has been or is now being quarried, nearly level to steep dumps of waste rock and soil material , stockpiles of marketable stone, and open areas of upland.Permeability is restricted, runoff is medium to rapid and available water capacity is low.

b. Common usage:

Dryness and susceptibility to erosion severly restrict this area for plants, some areas do support a cover of grasses weeds or brush, and allow slight grazing. They do have the potential to be used for certain kinds of recreation, wildlife habitat and storage of select solid waste.

7. Orthents (943)

a. Permeability:

This area consist of landfills constructed to dispose of refuse . These manmade soils are on flood plains, uplands and terraces. They are made up of several feet of refuse in trenches covered with a thick layer of soil material. In a typical area the cover is a mixture of cherty clayey, cherty loamy and loamy soil about 40 inches thick. In most places the cover material contains pieces of brick, glass, metal, plastic, or asphalt. Refuse extends from the base of the cover to an unknown depth. Peremability is moderate or slow in these areas, Runoff is most commonly medium but ranges from slow to rapid. The available water capacity is low. The erosion hazard is slight to severe. Where sewage sludge has been spread on the surface, the upper part of the fill material is dense and compacted.

b. Common Usage

Most areas of this type have a scant to fair cover of grasses or legumes, and weeds. The potential for grasses and legumes is good, but poor for trees because of the low water availability. Plants grown on any of this land that has had sewage sludge on the surface could receive toxic metals. Building site potential is low because of the high gas level in the refuse that underlies this area and most areas are subject to subsidence.

C. Climatology

1. Temperature

Green County is hot in the summer, especially at low elevations, and cool in the winter, especially on mountains and high hills. The published soil survey of Green County lists temperature readings taken at Springfield, Missouri, for the period 1951-1975. For spring months (February, March and April), the average daily temperature ranges from 47.0 - 67.7 degrees F. with average nightime lows ranging from 26.1 - 44.3 degrees F. Summer months (May, June, and July) have average daily temperatures between 76.2 and 89.1 degrees F., with nightime lows between 53.6 and 66.3 degrees F. Autumn (August , September and October) is characterized by average daily temperatures ranging from 88.6 to 70.3 degrees F and average nightime lows from 64.8 to 46.3 dgrees F. Winters in Green County are charcterized by average daily temperature ranging from 55.7 to 43.0 degrees F and average nightime temperatures ranging from 34.2 to 22.1 degrees F.

The first freezing day of the fall (i.e., the first day with a low temperature below 32 degrees F) usually occurs during the first half of October. The last freezing day of the spring usually occurs by the first week in May. This results in an average growing season between 168 and 206 days in length. The lowest recorded temperature in the City of Springfield was - 11 degrees F and occured on February 2, 1951. The highest recorded temperature occured on July 14, 1954 and was 113 degrees F.

2. Precipation:

Rainfall in Greene County is fairly heavy and well distributed throughout the year. Snowfall occurs nearly every year , but on the average, snowfall cover lasts only a few days. The total annual precipitation occuring at the City of Springfield averages 39.74 inches. Sixty percent of this precipitation occurs throughout the months of April through September. The heaviest one-day rainfall for Springfield was 4.82 inches , occuring on June 9, 1975. Thunderstorms occur about 60 days each year , with most thunderstorms occuring during the summer months. Average seasonal snowfall in Greene County is 14 inches , with an average of 8 days having at least one inch of snow on the ground . The greatest snow depth at any one time between 1951 and 1975 was 17 inches.

3. Humidity:

The average relative humidity in midafternoon is about 60 percent. Humidity is higher at night , and the average at dawn is about 80 percent. The percentage of possible sunshine is 70 percent in the summer and 50 percent in the winter[26].

D. Geography :

Site Remediation Planning for this waste disposal site will be heavily influenced by two sets of topographic conditions: (a) those existing prior to development of the Murray Landfill and (b) those conditions presently found at the site.

1. Topography

a. Pre-development topography :

Prior to development of the Murray Landfill, the site area was characterized by a moderately sloping bedrock hillside (lying at the Northeast quarter of Section 34) bounded on the Southwest and South by steep river cut hillsides . The hillside topography was dominated by a NE-SW trending ridge and intervening ephemeral stream valley and an Eastern hillslope. Slopes of the river-cut hill boundary were approximately 20% or greater . The remaining bedrock terrain slopes were as much as 10 to 15 % on the East and averaging less than 5% for most of the bedrock surfaces. The remainder of the landfill site, which has received the bulk of the waste disposal, was a nearly horizontal flood plain, lying approximately 10 to 15 feet above the normal flow stage of the river.

b. Post-development topography:

The post-development topography reveals that Murray Landfill is dominated by heavy fill areas that run almost due East to West that contain a varying amount of waste products. A drainage valley runs from the North center of the landfill to the SW into the Little Sac River. The river channel has been narrowed and straightened along the Southern boundary and a floodplain of approximately 200 feet exists along this boundary. As you approach the Western boundary , this floodplain decreases tremendously, so that on the West the distance from the waters of the Little Sac to fill waste is dropped to about 25 feet. The contours of the landfill vary at sharp intervals which show several separate lifts indicating varying depths of waste deposits.

c. Vegetation:

Pre-development vegetation on the Bedrock hillslopes apparently consisted of wild - forage maintained for grazing animals. It is suspected that this vegetation was supported on thin , residual soil , probably no more than 3 to 5 feet in thickness. This assessment is also supported by the current presence of a 1-acre cemetary remaining as elevated ground, located about 650 feet West of the common Section corner and about 75 feet South of the Section 26/34 boundary line. The only substantial borrow source for landfill cover could only have been the Little Sac River flood plain.

B. Demography

1. Population Density:

In the immediate area of the Murray Landfill, population is scattered and widely distributed. There are several single family dwellings located on one acre + sites, and the surrounding area can be described as a rural setting. However, within three miles of the landfill is the City of Springfield with a population in excess of 200,000.

2. Avenues of Transportation:

State Route 13 passes within one-half mile of the landfill and a spur from

SR13 was the primary access route during dumping operations. There are several unimproved roads that run within a mile or so of the landfill but vehicular access is virtually impossible except through the access road from SR 13. The Little Sac River could not be considered a navagible stream except for a few pleasure craft, however, access to the landfill from the river is easily accomplished. Overland access by foot is possible, but does not appear to be a serious concern because of the relative isolation enjoyed by the site.

3 . Land Use

a. Agricultural:

In the Greene County area beef and dairy cattle farms provide the major share of farm income . Production of feed and cash-grain crops is concentrated on the best uplands and river bottoms. Terraces are available and needed fo these uses. Major crops are wheat, soybeans, grain sorghum and corn. Forage crops (grasses,legumes, small grains, and forage sorgum) are produced on all kinds of land from small forest glades to big river bottoms. In the immediate area of Murray Landfill, livestock is the prominent operation, and almost all residences have a small garden for personal use. Production of commercial crops is extremely limited or non-existent.

b. Natural Resources

The most important mineral resources in the area is the Burlington-Keokuk limestone. In some places the formation is as much as 150 feet thick and is used in the manufacture of Portland cement, lime, asphaltic concrete, bituminous surfacing, road metal and base stone. Other limestone, as well as the dolomite formation have been used for dimension stone or base stone or both. There are several areas located in the vicinity of the Murray Landfill that have been former quarries, including one sited in the Northeast corner of the landfill itself.

The numerous caves in the area are known for attracting tourists. Greene county has more caves than any other county in Missouri, with Crystal Cave and Fantastic Caverns being the largest and best known. Fantastic Caverns , a much lauded tourist attraction, is within one mile to the West.

c. Residential

This area can be considered almost rural in its composition. However, most of the homes are on 1 to 10 acre sites and cannot be considered farmsteads. This obviously is a site for people who do not want to reside in tract homes in the city limits and commute to work in Springfield. Due to projected growth in the Springfield area , a safe assumption can be made that this area will experience considerable residential growth in the next 20 years and will probably be a residential subdivision.

d. Recreational:

Two major recreational sites are in the near vicinity of the Murray Landfill. Ritter Springs Park, which is owned and managed by the City of Springfield borders the Southern edge . It is separated from the landfill by the Little Sac River and a six-foot tall fence. Fantastic Caverns is located with one mile of the Murray Landfill and has been identified by the U.S. Heritage Conservation and

Recreation Service as a potential national natural landmark. Additionally, the cave is a habitat for three species of animals on the Missouri list of rare and endangered species [27].

Chapter 5: Pathways for Contaminant Transport

A. Hydrology

1. Drainage Network

There are two major drainage basins located in the vicinity of the City of Springfield. The Sac River basin in the northern part of the area and the James River in the southern part. All runoff from small rivers, creeks and ephemeral streams eventually reach these two major rivers. The City of Springfield is located on a drainage divide between these two basins, with most of the City's domestic water supply coming from stream impoundments and springs in the Sac River basin, while a large portion of this water is eventually discharged into the James River through the Southwest Sewage Treatment Plant in Wilson Creek. Except for this man-made interaction , there is no contact between the two basins .

The major streams are sustained during low-flow periods by the outflow of ground water from natural underground reserviors in the soluble carbonate bedrock. A number of small tributary streams are affected by the presence of underground dissolution cavities during low-flow , which causes water loss to the bedrock and subsequently interrupted flow. Due to an uneven distribution of permeability caused by the variable development of karst features,depending on relative solubility (limestone, high ; dolomite,low) of bedrock underlying these streams , they will either gain or lose water depending upon their elevation.

2. Surface Water:

a. Little Sac River :

The Little Sac river originates northeast of Springfield and flows westward into Fellows Lake and then into McDaniel Lake. These impoundments were built for drinking water supply use by the City of Springfield. In the vicinity of the Murray Landfill, the Little Sac River is the primary collector for small springs and ephemeral streams that feed into the Sac River in Dade county, several miles north of the study area. All waters collected by the Little Sac become part of Stockton Lake. In the immediate area , it has a drainage basin area of approximately 39.0 square miles with feeder streams of South Dry Sac Creek, Spring Branch, and Pea Ridge Creek. There are two distinctly different river regimes in the site area,. As the Little Sac River approaches the site from the East, crossing the Section 34-35 boundary the river channel is meanderous and characterized by numerous sand-bars. After traversing three complete meanders over a distance of 600 feet the Little Sac Channel becomes tightly constrained on the SW by limestone cliffs and a conspicously straight flood plain channel to the NE. The flood plain again widens at the extreme NW portion of the site for its final 200 foot reach. Based on photo interpretation of the 1960 coverage, it is apparent that the original flood plain deposits extend from the old flood plain surface to considerable depth, probably 25 to 30 feet.

b. South Dry Sac Creek:

The South Dry Sac creek is the major tribitutary steam that flows into the

Little Sac. It can be considered to be almost ephemeral along most of its reach, with discharge being primarily outflow from a series of springs and seeps. This creek runs along the side of the Fulbright Landfill, an EPA Superfund Site. It discharges into the Little Sac about two miles north of the Springfield City limits immediately crossing under U.S. Highway 13. Just prior to reaching the Little Sac, it receives discharge from the Northwest Sewer Treatment Plant and Water Works, which causes a marked increase in measurable flow.

c. Ephemeral Streams :

Due to the geography of this area there are a number of ephemeral streams that feed into the drainage basin, with Spring Branch and Pea Ridge Creek being the most significant. As stated earlier, they are underlain by varying amounts of karst and they may lose part of their flow or disappear entirely where the underlying rock is very permeable. They also may gain water where the rock is less permeable and the ground water surface is above stream level. These streams are the principle conduits for water flow during periods of wet weather but have no appreciable effect during other periods.

3. Flood Potential:

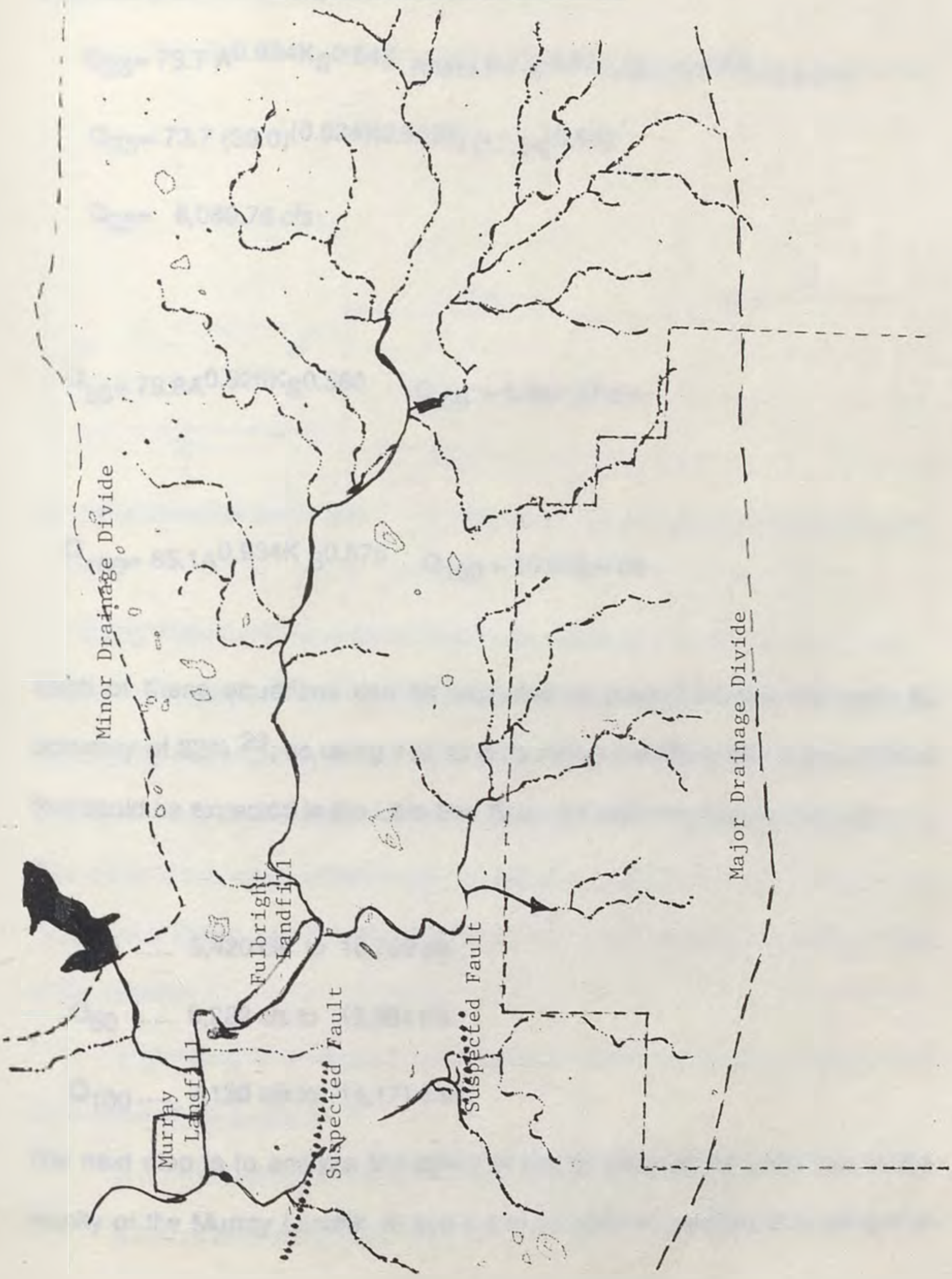
The Murray Landfill is located on the floodplain of the Little Sac River and as such is subjected to the possibility of frequent flooding. Floodplains are built up primarily from deposition of sediment in the river channel and deposition of fine sediments on the floodplain when flooded. Floodplains tend to be flooded at fairly low recurrence levels. The Little Sac does have a basin area of approximately 39.0 square miles immediately prior to reaching the Murray Landfill and the flood probability should not be discounted.

a. Basin Area (Figure 12)

(1). Peak Flows and Method of Calculation:

There are several methods of calculating peak flows for this basin area that can be considered. The first and oldest method is called the Rational Method, and is defined by the formula Q = CIA, Q = peak discharge in cfs, C is a runoff coefficient depending on characteristics of the basin, I is the rainfall intensity in inches per hour and A is the drainage area in acres. Due to the large number of assumptions on which this formula is based, and the fact that it is such a generalized formula ,the ones developed by L.D. Hauth, for the U.S. Geological survey and used in Water Resources Report number 34, 1978, " Water Resources and Geology of the Springfield Area, Missouri " seems to be more accurate for our local area. Hauth has developed a series of equations used to compute the peak discharges with selected recurrence intervals. Only two basin area characteristics are needed, drainage area (A) in square miles and average main-channel slope (S) in feet per mile[28]. By using a planimeter on the drainage area as outined in Figure 5 the basin area is approximately 39.0 square miles. A measurement of the channel slope of the Little Sac River from the Eastern edge of the basin area gives a slope of 17.54 feet/mile.

FIGURE 12: BASIN AREA SKETCH



(2) Computations

Hauth's equations for the basin area, with 25, 50 and 100 year recurrence intervals are:

$Q_{25}= 73.7\ A^{0.924K}S^{0.542}$ where $K= A^{-0.02} = (39.0)^{-0.02} = 0.9293$

$Q_{25}= 73.7\ (39.0)^{(0.924)(0.9293)}\ (17.54)^{0.542}$

$Q_{25}=$ 8,089.76 cfs

$Q_{50}= 79.8A^{0.926K}S^{0.560}$ $\quad Q_{50}$ = 9,287.37 cfs

$Q_{100}= 85.1A^{0.934K}\ S^{0.576}$ $\quad Q_{100}$ = 10,655.0 cfs

Each of these equations can be expected to predict correct flow with an accuracy of 33% [29]; so using that as a boundary condition, the range of flows that could be expected in the Little Sac River, for each recurrance interval is:

Q_{25} ...... 5,420 cfs to 10,759 cfs

Q_{50} ...... 6,222 cfs to 12,351 cfs

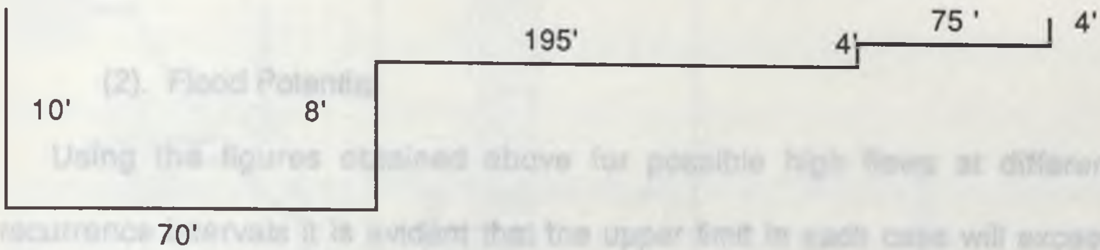
Q_{100} ...... 7,139 cfs to 14,171 cfs

The next step is to analyze the ability of the channel of the Little Sac in the vicinity of the Murray Landfill to see if it is capable of handling this amount of flow.

b. Little Sac River

(1). Channel Analysis

The Little Sac River channel cross-section is as shown in Figure 13 below:



All measurements are in feet Figure 13 : Cross section Little Sac River

Using Manning's Formula for maximum flow based on channel geometry $Q = A\ (\ 1.49/n)\ R^{2/3}S^{1/2}$ [30], we can estimate the maxium flow that can be handled by this shape channel. Due to the realignment of the river channel, the best geometric approximation is a rectangular shape. However , in order to determine if this channel will flood we need to consider the upper limit of the rectangular shape as ending at the 8 foot side. The following parameters need to be defined:

n = Manning' s n ; a good estimate for this shape and type channel would be between 0.02 and 0.04 [31].

R = hydraulic radius ; given by 70 ' * 8 '/70 + 2*8 = 6.51 ft

A= Area of channel ; 70 * 8 = 560 ft^2

S = Slope ; in feet, convert 17.54 ft/mile = 0.0033

Q_{max}= (560 ft^2)(1.49/0.02)(6.51 ft)$^{2/3}$(0.0033)$^{1/2}$

Q_{max} = 8,357.69 cfs

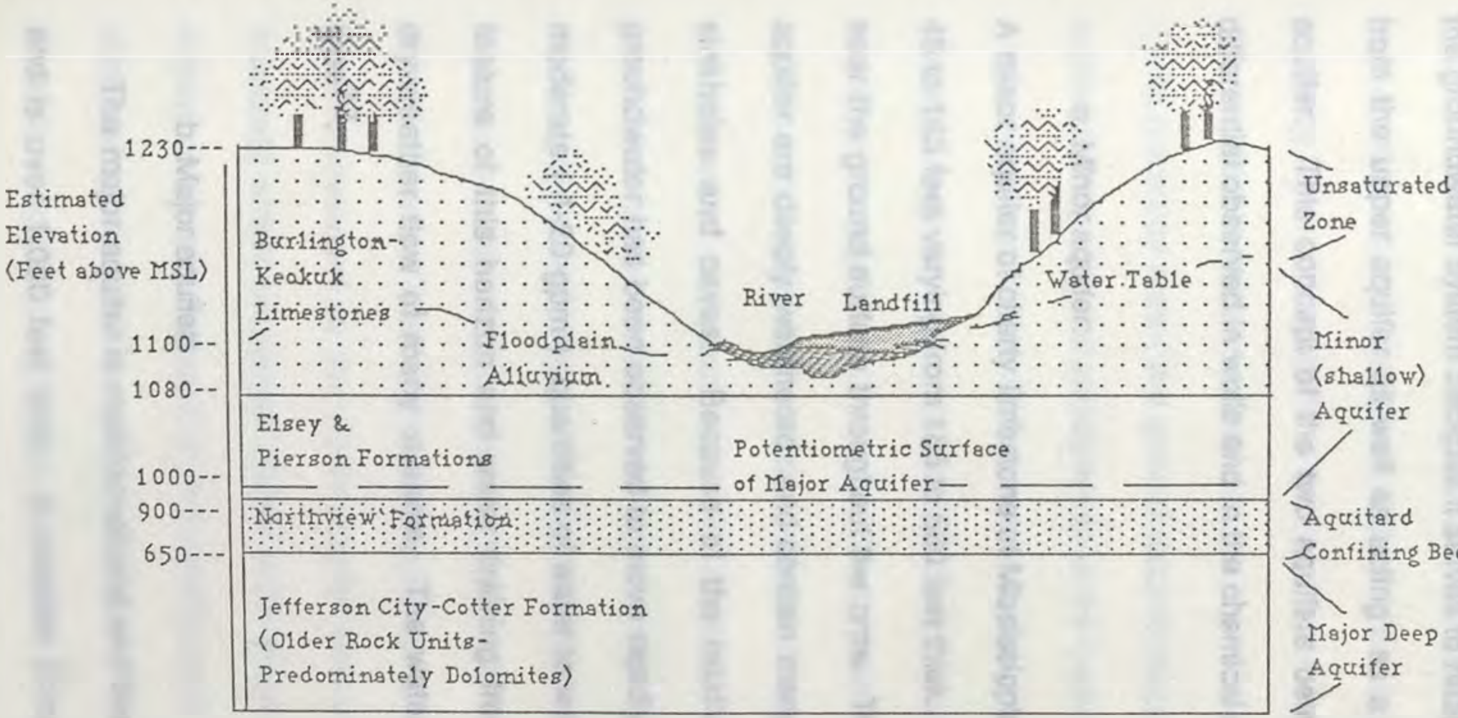
(2). Flood Potential

Using the figures obtained above for possible high flows at different recurrence intervals it is evident that the upper limit in each case will exceed the capacity of the channel. The lower limit in all cases will be held by the channel. However, if the equations prove to be accurate, the maximum channel capacity will be exceeded on the 50 year (9,287 cfs) and 100 year (10,655 cfs) flood. The next question is that if the maxium channel capacity is exceeded will some of the first lift be eroded.

By adding the additional 2 feet in height and 195 feet in length, the channel capacity rises to 11,922.5 cfs. This means that the water will most probably reach the first lift , but it will not overflow it. However, any type of flood over the banks of the river channel will reach leachate pools and will cause the leachate to be distributed downstream.

4. Groundwater

In the vicinity of Springfield, there are two separate and distinguishable aquifers that provide the subsurface water supply for the area (Figure 14).



Note: The cross section shown does not depict the faults and fractures typically associated with the karst topography of the region.

Figure 14: Geological Cross-Section Drawing

These aquifers are separated by an aquiclude that consists of brownish siltstone and blue or bluish-green shale that is from 5 to 80 feet in thickness. This aquiclude is called the Northview Formation and has a major impact on the groundwater system because it serves to retard the groundwater recharge from the upper aquifer as well as acting as a confining layer for the lower aquifer. This concept of the two aquifers being distinct is based on head differential observed in wells and in the chemical quality of the water[32].

a. Minor aquifer:

A minor aquifer of cherty limestone of Mississippian age is located at a depth of 45 to 185 feet varying from 185 to 560 feet thick. These rocks are present at or near the ground surface throughout the area. The rocks making up the minor aquifer are deeply weathered and contain many dissolution features such as sinkholes and caves. Because of the relative openness of the system, groundwater has been observed to move rapidly. This system yields small to moderate (1-20 gpm) quantities of water to wells. Springs are the common feature of this horizon and water draining from this aquifer maintains the dry-weather flow of many streams. The water is of a calcium-bicarbonate type[33].

b. Major aquifer:

The major aquifer is multiformational and lies at a depth of 250 to 790 feet and is over 1,000 feet thick. It consists primarily of dolostone with minor sandstone strata. Except in the outcrop area, water is under artesian pressure between relatively impermeable strata. Wells open to the total thickness of this aquifer are reported to have been pumped at rates of 2,000 gpm. Water from this aquifer is a calcium- magnesium bicarbonate type. The top of the igneous rock is about 2,000 feet below the land surface and serves as the bottom confining layer of this aquifer.

c. Groundwater movement

In the study area , the ground water in the major aquifer generally moves northwest following the structural dip of the bedrock away from the Ozark uplift. A ground water divide is located at approximately the Greene - Christian County county line, 10 miles south of our study area. Ground water movement in the minor aquifer is much harder to define due to the large number of surface-subsurface connections . These connections facilitate movement of surface water pollutants into the groundwater. Normally, groundwater movement is downward in response to gravity. Water levels in the minor aquifer are generally higher than those in the major aquifer, therefore , potential movement is downward. However, the Northview formation retards downward water movement and acts as an upper confining layer to the major aquifer. Water movement to the major aquifer can occur where the Northview is breached either by natural means such as joints and faults or by artificial means such as uncased or improperly cased wells. The location of the suspected Ritter fault, as shown on Figure 12 , should give some concern to possible contamination of the major aquifer [34].

D. Other transport mechanisms

a. Unauthorized site use

The Murray Landfill is located next to Ritter Springs State Park. Access to the landfill is prohibited by the use of a wire fence. The proximity of the landfill to the park and the relative ease by which the fence could be climbed leads to the conclusion that overactive park-goers could easily gain access to the landfill site. The remaining borders of the landfill are open, although there are occasional sign posted stating no tresspassing. Anyone who wishes to walk or even drive on the landfill will not be stopped. There are no signs posted warning of potential hazardous waste in the area.

3. Potential Receptors

Several nice homes, as well as Ritter Springs Park are located within the area immediately surrounding the Murray Landfill. The wells that service these homes and the Park, therefore, are the potential receptors of any contamination that could possibly be released from the landfill. Airborne contamination would also reach the same population sector. The area of concern for any transport of waste is the area that comprises the downstream basin of the Little Sac river. In this area there are several small towns with populations of less than 1,000 , as most of the area consists of small farming operations. Additionally, the Little Sac flows into Stockton Lake, a major impoundment and recreation center for Southwest Missouri.

4. Public Health Impacts:

Referring to Waste Characteristics, there is evidence that certain wastes disposed of at the Murray Landfill are possible carcinogens or are poisonous. Health impacts from the release of wastes from the landfill could include nausea; eye, nose and throat irritation; lung irritation, and possible long-term cancer development. The Center for Disease Control should perform an in-depth study of the health impacts arrising from the releases from Murray Landfill once the types and amounts of wastes disposed of at the site have been quantified.

5. Environmental Impacts

The vegetation placed on the landfill as part of the final cover appears , upon visual inspection from the Park , to be thin or dead in some areas. Environmental impacts from the possible release of contaminants from the landfill include destruction of nearby vegetation as well as the contamination of the Little Sac River. This contamination could also be ingested by area animals and waterfowl. Animal droppings will spread the contamination even futher from the site. The consumption of an animal that has ingested contaminated vegetation or another contaminated animal by a person increases the public health risks caused by the hypothetical releases.

Chapter 6: Legal Implications

A. Laws:

The Environmental Protection agency has responsibility for toxic substances under the following eight laws :

1. Clean Air Act, Section 112: which lists and controls hazardous air pollutants.

2. Toxic Substances Control Act, Section 6: Regulates the manufacture, use and disposal of toxic pollutants.

3. Clean Water Act, Section 307a: Sets criteria for the cleanup of toxic water pollutants.

4. Safe Drinking Water Act, Section 1412b: Sets maximum contaminant levels for drinking water pollutants.

5. FIFRA (Pesticide law) Section 6: Sets standards to control toxics in pesticide use.

6. Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), Section 102,104: Controls toxics in spills; cleans up toxics found in waste disposal site (SUPERFUND)

7. Resource Conservation and Recovery Act, Section 3001: Sets criteria for defining toxic wastes.

8. Marine Sanctuaries Act, Section 102: Controls ocean dumping of wastes.

Of these eight laws , the primary ones dealing with the problems at Murray Landfill are CERCLA, Resource Conservation and Recovery Act (RCRA) and the Clean Water Act. The major provisions of these three laws will be reviewed with emphasis on the impact on Murray Landfill.

B. CERCLA, RCRA, Clean Water Act

1. CERCLA (PL 96-510) was enacted on 11 December 1980 with a five year life originally funded at $1.6 billion. It was designed as a response statue so it does not require promulgation of any regulations and can respond to any release of contaminant into the environment. In March 1981, the EPA was assigned the task of developing an interim priority list of hazardous waste sites to determine how the expenditure of this large sum of money was to be governed. This National Priority List was issued as part of the National Oil and Hazardous Substances Contingency Plan (NCP), which will be discussed later. CERCLA has a state preemption rule which allows the state to assume the lead in any NPL clean up project in their boundaries. Some of the incentives offered to encourage state participation has been funding provisions, particularly a 90/10 provision for privately-owned sites with state management, an improved EPA management system which identifies an EPA point of contact for each state project, timely release of Superfund monies, up-front funding (1-2 percent) for management of cleanup activities and the inclusion of two years of operating and maintenance costs in the Superfund allocation; then seek long term state funding for operating and maintenance [35].

2. Resource Conservation and Recovery Act

This act requires the EPA to develop criteria for identifying hazardous waste using toxicity , persistency , degradability in nature, potential for accumulation in tissues as well as other hazardous traits such as corrosiveness and flammability. These criteria are used as a basis for developing and issuing a list of hazardous substances. The EPA is given broad authority to prescribe standards that may be required to protect human health and environment. There are several sections in this act that apply and have a definite bearing on the Murray Landfill situation. Section 3002 requires standards for generators of hazardous waste covering record keeping,reporting,labeling, use of appropriate containers and a manifest system to insure the waste is processed on-site or with the required permit, as part of a cradle-to-grave system for hazardous waste. Section 3004 requires standards covering storage and disposal facilities, based on treatment, location, construction and operation of disposal sites.

Four more significant features were incorporated to the implementing regulations in 1980. First, an " extraction procedure" that attempts to measure the likelihood that wastes will leach hazardous concentrations into the groundwater, second, small generators, (those producing less than 1000 kilograms of hazardous waste per month) are exempted, third,interim standards are implemented while permit applications are pending, and fourth, the requirement that owners of disposal facilities must provide post-closure care for 30 years [36]. In addition to its regulatory powers, RCRA also gives EPA authority to seek injunctive relief to enforce the desired actions.

3. Clean Water Act

The Federal Water Pollution Control Act was substantially amended in 1977 and was designated the Clean Water Act. Authorization was given to allow extensions of the pollution control deadline implaced by the FWPCA and more specific requirements were devoted to define three categories of pollutants. Different dates for compliance with the "best practicable" and "best available technology economically achieveable " were imposed based on the seriousness of the type pollutant discharged. These three types of pollutants are ; (1) toxic pollutants, as specified by a list, (2) convential pollutants, BOD, fecal coliform, suspended solids and pH; and (3) nonconvential pollutants which include those not classified in the other two areas. A new standard, "best conventional pollution control technology " was established for the conventional pollutants. All of these standards were required to be achieved by July 1, 1984 [37].

C. National Contingency Plan

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) not only establishes a fund for financing the cleanup of uncontrolled hazardous waste sites (generally referred to as Superfund), it also requires that procedures be established to evaluate remedies, including analysis of relative cost, to determine the appropriate extent of remedy and to assure that remedial measures are cost-effective. Such remedial measures must be, to the extent predictable, in accordance with the National Contingency Plan and must balance the needs for protection of public health, welfare, and the environment at the facility under consideration with the availablity of amounts from the Fund to respond to other sites which present or may present a threat to public health, welfare or the environment.

The authority and responsibility for carrying out these provisions under CERCLA has been given to the U.S. Environmental Protection Agency (USEPA). The plan for carrying out these provisions has been incorporated in the revised National Contingency Plan (47 FR 31180, July 16, 1982; 40 CFR 300) as Subpart F (40 CFR 300.61 - 300.71). The National Contingency Plan (NCP) sets forth the process by which remedial actions will be evaluated and selected and the factors that will be considered in this process.

The NCP requires a detailed investigation of the uncontrolled waste site in order to obtain the data necessary to define the problem and evaluate alternative remedial measures. Section 105 of CERCLA provides the requirement to develop "... methods for discovering and investigating facilities at which hazardous substances have been disposed of or otherwise come to be located "[38]. Accordingly , the NCP recommends a phased approach for investigating remedial action at a site. Subpart F, Section 300.68 of the NCP outlines the steps that lead to implementation of appropriate remedial actions. Section 300.68(f) , in particular, indicates that: " A remedial investigation should be undertaken... to determine the nature and extent of the problem .. "[39]. Those site characteristics which determine the need for remedial measures, and thus drive the site characterization process, are listed in Subpart F, Section 300.68(e) of the NCP. Finally, Subpart F, Section 300.66 (c) (1) specifies " .. monitoring, surveys,testing and other information gathering.. "[40] in connection with enforcing legal requirements.

D. Initial Actions by Region VII, EPA

In June of 1980, after receiving information about two possible hazardous waste sites operated by the City of Springfield, Region VII contacted the Solid Waste Management Division of MDNR and informed MDNR that Fulbright was going to be listed in the tracking system and wanted to know if MDNR desired the lead on this project. Apparently Region VII, EPA considers Murray Landfill to represent a threat to the health and welfare of local residents. The position of EPA is governed by information from interviews with companies and employes. Similarities in nature of waste , siting, design, operation and dumping practices link the two (Fulbright and Murray Landfills) together. Apparently it was the plan of Region VII to negotiate with the City of Springfield toward site characterization , Remedial Investigation, and a Feasibility Study , to be planned and conducted by the City

1. Initial actions by State of Missouri:

MDNR instructed the DEQ, Springfield Office to conduct a preliminary investigation into Fulbright Landfill. The Investigating team filed a Potential Hazardous waste Site Identification and Preliminary assessment Report, EPA Forms 2070-8 and 2070-2 and conducted a number of interviews with former City of Springfield and Royal-McBee employees. MDNR worked with the City of Springfield in their monitoring effort and assisted them in their sampling effort.

They used the publicity associated with these landfills to push for a Missouri Hazardous Waste Law.

2. Initial actions by City of Springfield:

The City proposed a monitoring plan which they would fund for a period of six months from July 1982 through December 1982, after which they wanted to meet with MDNR and EPA to determine if there was any futher need to monitor these two landfills. The City discontinued sampling after December 1982. The mayor wrote a letter to MDNR in September 1983 requesting that MDNR revise their thoughts about both Fulbright and Murray and take them off the Missouri Hazardous Site List. This letter was written after the Fulbright site was proposed for the National Priority List. Due to the fact that the City is a potentially liable party and has introduced pre-remediation construction activity into the sites, the City is being assisted by EPA in the lead on this project.

3. Assumption of lead by Region VII, USEPA

In a letter dated May 25, 1984 to Dr David Bedan, Director, Solid Waste Management Program , MDNR from Robert Morby , Chief Waste Management Branch, Air and Waste Management Division, EPA Region VII. EPA " will pursue a RI/FS at both sites. We will also implement remedial actions at both sites as appropriate. At this time we are discussing with the City of Springfield the possibility of the City conducting the RI/FS under a consent administrative order " [41].

An Action Memorandum was written by David Wagoner, Director, Air and Waste Management Division, Region VII, USEPA to Morris Kay , Regional Director, Region VII, EPA on 19 September 84: The purpose of this memo was to request authorization to undertake a remedial investigation and feasibility study (RI/FS) at the Fulbright/Murray Landfill site in Springfield, Greene County , Missouri. The EPA Region VII will have the lead management responsibility for each activity included in the RI/FS. Particularly noteworthy is the enforcement provision which state that " the City of Springfield is a potentially responsibile party , and has expressed an interest in conducting the RI/FS. It is our intention to develop the workplan for the RI/FS and present it to the City in an Administrative Order for the City to conduct the actual work. If the city does not follow through and conduct the EPA workplan for the RI/FS in a reasonable and timely manner , EPA will conduct the project. " Morris Kay approved on a recommendation for funding of $ 500,000.00 for the remedial investigion and feasibility study at the Fulbright/Murray landfills[42].

Chapter7: Conclusions and Recommendations

A. Tenative Conclusions:

The Murray Landfill is an uncontrolled hazardous waste site and should be considered as a potential danger to the population surrounding the City of Springfield. The close link to Fulbright Landfill and the use of Murray Landfill by Royal-McBee leaves little doubt as to the fact that hazardous waste contamination that exists on the site. The employee interviews regarding the operating procedures at Fulbright and Murray Landfill indicate that there was no specific design provision to receive hazardous waste. No mention was made of using a liner , although it is probable that most hazardous waste was dumped in the limestone quarry . The limited sampling conducted by the City and MDNR give indication of a variety of hazardous waste being present, especially the concentrations of copper, chromium and cyanide, all of which can be associated with the manufacturing of typewriter and electroplating operations.

A conceptual model of the site would indicate that there is probably a simple relationship between the site and the surface water of the Little Sac river system. Although penetration of the Northview formation cannot be ruled out, there is reason to believe the shallow water table outcropping of the minor aquifer into the surface water system is the dominant pollutant pathway. The routes of entry of contamination into the Little Sac are from seasonal flooding, outcroppings of seepage and entry through runoff channels and subsurface seepage into the river bed and banks. As the groundwater vector and the river tend to flow toward the Northwest, the pollution will probably not effect the population of the City fo Springfield, but instead will contaminate the private, shallow well systems of local rural residents.

The existing sampling is not sufficient in terms of location, depth, and chemical species. A combination of technologies should be employed, wells, perimeter and seep borings, and priority pollutant analysis. An analysis of water and sewer district quality and flow records, stream flow records, water quality mangement plans and construction grant applications should be conducted. Field work to determine actual flows, sampling above and below the site and in tributaries. Wells drilled and a soil profile taken, flow direction and pH measured and a groundwater sample taken for analysis of the tracer pollutants , metals, cyanides, total organic carbon and total volatile organics. A host of items need to be accomplished and will be considered in the recommendations portion of this Chapter. A definite need exists for a complete Remedial Investigation and a Feasibility Study that comply with EPA guidelines.

B. Implications of Title 40, CFR ,Subchapter I-Solid Waste,

This Subchapter sets forth the rules for EPA and the requirements that owners or operators of treatment, storage or disposal facilities must follow. Murray Landfill can fit into the definition of a disposal facility and can be considered to be entirely closed because all the closure requirements were met that existed at that time. The owner (City of Springfield) qualifies for interim status which provide administrative requirements, monitoring and closure standards and an abbreviated set of technical and closure and post-closure cost estimate requirements . However, if the City continues with the construction of the wastewater treatment plant it becomes a generator and is subject to the more stringent requirements established by Part 264, 40 CFR. The City must discover how bad the site really is (a) before building or (b) while building or (c) after building -in which case the owners of the plant and interceptor sewer assume the responsibility for the hazardous waste. The City of Springfield would have sole responsibility and no remedy could be collected from the manufacturing companies that disposed of the waste.

This proposed construction has caused some serious concern to for regulatory agencies as evidenced by a Memorandum to File: Fulbright and Murray Landfills (City of Springfield) Greene County from Tom Gredell, Environmental Engineer, Waste Management Program, MDNR. This memo states the requirement for coordination between Water Pollution Control Program and Waste Management Program for:

(1) Excavation of an inactive landfill

(2) Excavation of a possible uncontrolled site

(3) Collection and disposal of leachate

Additionally the memo states that worker safety procedures have to be included in contract, solid waste that is excavated will have to be properly disposed of, and construction sites will have to be dewatered. All water encountered will be considered to be leachate. Three disposal methods are recommended, (1) apply the leachate to the landfill surface and (2) disposal through the existing wastewater treatment plant (3) chemical and physical treatment and then by-passing the existing plant . (1) and (2) are the preferred methods but, it is recognized that (3) may be used if too much water (leachate) is obtained.[43]

From construction on the site any Hazardous Waste discovered will be regenerated and there is no disposal option. Any digging on Fulbright, already in the Superfund list, is in violation of CERCLA guidance[44]. The City of Springfield does not have any permit to dispose of hazardous waste. Even in the event of a regulatory determination to the effect that hazardous waste encountered at either of the uncontrolled sites can be redisposed of in other sections of the same landfill, such a plan would require the adhearance to CERCLA regulations. The cost of this adhearance would be borne by the owner of the facility.

1. Options available to USEPA Region VII

It would appear that the present situation lends itself to only one option, that is to characterize by means of a full-scale Remedial Investigation the hazardous waste potential of the site before they build anything. Two scenearios yield this option. The first being the excavation of hazardous waste during the course of construction of the plant and the results of this encounter. The second being the lack of detection of hazardous waste which are indeed present on the site, detected during later phases of plant operation, i,e, expansion, closure; the initial consequences of this discovery would be compounded by the time delay and possible exposure to facility workers.

C. Recommendations for Contractual Remedial Investigation

1. Phasing and coordination

a. Phase I

The objective of the Phase I characterization is to compile sufficient site characterization data to understand the nature and magnitude of problems at a site and develop a plan for subsequent detailed characterization efforts. With respect to problem definition , the Phase I characterization of sources, pathways and receptors should allow development of a conceptual model of potential site hazards. The components of this conceptual model should include the known or suspected sources of contamination, the probable pathways by which these contaminants can migrate, and the potential receptors which can be impacted by contaminant migration. The results of Phase I characterization is used in the Feasibility Study to initially screen remedial action alternatives and to develop a plan for conducting the Phase II characterization effort. The conceptual model must be considered when developing Phase II data collection activities

Typically , the Phase I characterization will not be very detailed, and is more qualitative than quantitative in nature. The level of detail should be adequate to identify the types and quantities of contaminants present at the site and to develop a general understanding of the behavior of these contaminants and their potential impacts. The results of this phase should provide a general indication of the type and severity of the hazards posed by the site. The Phase I results must be sufficient to identify specific data required to quantitatively define the hazards posed by the site.

Phase I characterization efforts should initially be limited to existing data, particularly those data collected during performance of the site review assessment. If existing data are inadequate to meet the objectives of the characterization, limited additional data should be collected [45].

b. Phase II:

The objectives of the Phase II characterization is to collect quantitative data on all potentially important sources, pathways, and receptors. This information is used to:

1. Quantify the hazard associated with the site through an endangerment assessment of site conditions.
2. Identify the general categories of technically feasible remedial actions.
3. Produce a base-line assessment of environmental conditions.
4. Develop a physical model of contaminant transport at the site.

The Phase II characterization involves a greater level of detail than Phase I. The Phase II characterization should contain a detailed description of the types, quantities, and forms of contaminants at the site, a quantitative description of site and off-site characteristics affecting transport and fate of contaminants, and a quantitative description of existing environmental conditions at the site. The results of Phase II are used to develop a physical model of contaminant transport at the site. The physical model consists of the verified conceptual model plus the equations and boundary conditions that govern transport and the data required to solve these equations.

The Phase II characterization is needed when the results of Phase I indicate a significant potential risk of harm to human life or health or the environment. The Phase II effort supports the Feasibility Study by collecting the data needed to initially screen methods for remedying site conditions and to quantitatively decribe the potential and actual impact of the site.

Unlike the Phase I effort, Phase II generally requires substantial collection of new data. Chemical sampling and analysis is required to obtain on-site and off-site characterization. Hydrogeological and meterological studies are typically required to characterize the off-site transport of chemicals. Environmental monitoring is needed to establish the base-line environmental conditions around the site to assess potential impacts [46].

c. Phase III

The objective of the Phase III characterization is to collect detailed data on sources, pathways, and receptors shown by the Phase II endangerment assessment to be important. These data are used to quantitatively assess performance of technically feasible remedial actions, perform detailed risk assessments associated with implementation of each remedail action, and quantitatively assess environmental impacts of remedial actions.

To meet the above objectives, it is necessary to collect very detailed information during Phase III. In general, the level of detail must be adequate to predict the performance of spevific remedial actions and predict contaminant migration rates. Therefore, very detailed data must be collected (e.g., soil permeabilities, water level measurem,ents, contaminant concentrations, etc.) By this time, however, the site should be sufficiently characterized that data collection efforts are directed solely toward data that are necessary and important.

A Phase III characterization is needed when the results of the prior characterization indicate that a remedial action must be implemented. The Phase III effort is needed to obtain data to analyze, in detail, each technically feasible remedial action. This analysis is then used in the Feasibility Study to select the most appropriate remedial action. The analysis must include an assessment of the risk associated with each remedial action; that is, the offsite migration of contamination resulting from implementation of each remedial action and the resulting human health and environmental impacts must be evaluated. These risk assessments are performed using a predictive model of contaminant transport. The predictive model consists of the physical model developed during Phase II plus the conditions and constraints imposed by specific remedial actions.

The Phase III characterizations involves data collection techniques similiar to those in Phase II. Phase II is, however, conducted in much greater detail and only focuses on specific problem areas identified in Phase II [47].

2 . Recommended Scope

a. Phase I

(1) Review of Currently available data

The Phase I characterization is based initially upon currently available data. Maximum use should be made of such data because this will economize the collection effort. Phase I data are organized by Environmental Setting, Hazardous Subtances, Environmental Concentraions, and Potential Receptors. Environmental Setting includes data characterizing pathways as well as descriptions of receptor population distributions. Such data are typically available from published reports. Hazardous substances consist of source data, including waste and chemical data and facility characteristics. These data are typically available form prior site inspections. Methods appropriate for Phase I characterization consist primarily of reviews of existing records and published data describing site characteristics.

(2) Environmental Setting:

Existing data describing the environmental setting of a site are needed to obtain a general understanding of site conditions and a general perspective of site problems. Environmental setting data should include descriptions of site geology, hydrology, meteorlogy, demography, land use, flora, and fauna.

(3) Hazardous Subtances

Existing data describing hazardous substances at a site are needed to initially identify the type and magnitude of problems that may be associated with the site. Hazardous substance data should include descriptions of the types of hazardous substances present at the site, the quantities of these substances, their physical form, their dispostion, and facility characteristics affecting waste release.

(4) Environmental Concentration:

Existing data describing environmental concentrations of hazardous substances at and around a site are needed to initially assess the magnitude of site problems, develop appropriate initial response actions, and assure the safety of site workers and the public. These data should include any and all measurements of hazardous substances in environmental media, both on and off the site. Data should include the time and location of sampling, the environmental media sampled, concentrations of various substances, and the identity of the parties performing the sampling and analysis.

(5) Potential Receptors:

Existing data describing potential receptors are needed to help define the significance of potential contaminant migration at the site. Potential receptors include any populations which may be impacted by contaminants at or migrating from the site These can include human population, flora, and fauna, both on and off site. Data should include the identities of potential receptors , their populations and their location.

(6) Methods and investigations:

Methods appropriate for Phase I Characterization consist primarily of reviews of existing records and published data describing site characteristics. Limited data is collected and a limited analysis of that data is conducted; so that an initial assessment of the present and future hazards posed by the site can be estimated. A conceptual understanding (model) of the site should be developed that should include contaminant location and movement,hydrology, and potential exposure pathways and processes. It may be limited in detail and accuracy, depending on the availibility of data and expertise of personnel involved, but it serves as the basis for all future analysis and modeling efforts and is a critical element in the chain of investigation leading to selection of any remedial action.

(7) Development of a Quality Assurance /Quality Control Plan

The purpose of a quality assurance/quality control program is to insure that data generated during the activities are of known and sufficient quality so that they can be used to quantitatively assess the nature and extent of contamination at the site. Factors which must be considered early in the planning phase include an evaluation of the types of data needed, the allowable level of uncertainity, and the availability of data collection and assessment procedures to provide the desired level of reliability.

(8) Results:

The output for Phase I is a description of existing site characteristics and a preliminary assessment of the actual or potential hazard posed by the site. These results should be documented in an initial site characterization report which can be used to develop futher site activity. This report must be able to establish one of two things, either that no hazard is presented by the site and no additional activities are needed or that a potential hazard does exist which requires futher action [48].

b. Phase II:

The Phase II characterization is used to collect general source, pathway, and receptor data used to screen alternative technologies. The Phase II effort is meant to provide general information used to identify all appropriate technologies and , as such, the investigation must be broad in scope. Because of scheduling and programmatic constraints, Phase II may be the only time when such a full-scale characterization can be conducted. Therefore it is important that the scope not be unduly limited because of confidence placed on prior conceptualizations. If any potential sources, pathways, or receptors are eliminated from consideration during Phase II, this decision must be based on objective data rather than subjective judgement. The goal of any remedial action must be to prevent contaminants at the site from causing unacceptable adverse impacts to human health, public welfare , or the environment. Most Phase II activities involve field efforts aimed at making measurements on the environment.

(1) Survey the site and establish basis for futher action.

Environmental data must be collected from the site to further characterize the flora, fauna, land use hydrology, climate, and other conditions. These environmental data must support the human health exposure/risk assessments and provide information about what environmental factors may affect the acceptability of candidate remedial actions.

(2) Quantify concentrations and distributions of wastes.

The identity, concentration, and distribution of chemicals at the site must be determined. To model the environmental exposure/risk, concentrations of envionmentally-important contaminants must be determined at appropriate locations. What is actually present in the environment may differ from what is indicated to be present in available records. Records may be incomplete or erroneous. Wastes may have been transformed by chemical or physical reactions, or degraded into intermediate products by microorganisms. Key indicator contaminants must ne identified on basis of priority scores and environmental persistence scores.

(3) Identify risks of site, assuming no futher action.

At this point; the environmental endangerment assessment must include identification of potential risks to the environment and man beyond the borders of the site , assuming no futher action. Again priority scores and environmental persistence scores must be developed for the waste constituents known to be present. Assessment of the environmental exposure and risk must be conducted in concert with those individuals conducting sampling efforts developing a contaminant transport model for the site in Phase II.

(4) Evaluate environmental conditions affecting remedial actions

The major effort of this objective in Phase II is to identify the environmental conditions that can affect implementation of potential remedial actions. Detailed data on site-specific physical and biotic features are required to supply the appropriate infromation to the individuals evaluating various remedial alternatives. Physical characteristics include: climate, topography, soil type and permeability, groundwater, and surface water. Biotic characteristics include flora and fauna. Animal movements or migrations should also be noted because these can also contribute to contaminant migration from the site.

(5) Assess risks and impacts of remedial actions.

Implementation of a remedial action may impact the environment at or near the hazardous waste site. Evaluation of these potential environmental impacts are, in part, based upon the results of contaminant transport modeling techniques used to assess the effectiveness of remedial alternatives. In addition, environmental data must be collected to determine the potential impacts of remedial alternatives on plants, animals , crops, livestock,and aquatic environments. Much of this data may have been obtained during Phase I from available information or the limited sampling. However, detailed site collection of environmental data is often necessary to meet this objective.

(6) Results

Phase II studies are designed to characterize the site so that appropriate remedial actions can be identified. The results of Phase II characterization must integrate the geologic,hydrologic,chemical,and ecological settings to define the nature, extent,and impact of the contamination. Data collected during this phase is used to select possible remedial actions. An Endangerment Assessment detailing the degree of risk to human health and the environment that is posed by the quantified contamination at the site with no remedial action, a data base of source, environmental, and impact characteristic that is sufficient to evaluate the general feasibility of alternative remedial actions and to document the current status of the no-action alternative, a contaminant transport and fate model of sufficient detail to reliably predict the future effects of the no-action alternative [49].

c. Phase III

Data collected during Phase III are used to support selection of remedial action methods for a site. Selection of specific methods requires very detailed site characterization data. These data fall into two general categories, data for determining the effectiveness of methods and data for determining the implementation requirements of the possible remediation methods. The environmental exposure/risk assessment is more specific and detailed than in Phase II. The goal of this phase is to perform a detailed assessment of the environmental impacts of a finite set of specific candidate remedial actions. To achieve this goal, bioassays, microtox analysis, and detailed sampling of the site environment may be required. The five previously described objectives of environmental/risk assessment are still applicable in Phase II, however, the depth and specificity are much more pronounced.

(1) Survey the site and establish basis for futher action

Compilation of environmental data affecting implementation of a remedial action must be completed. Selected in-depth environmental sampling may be required.

(2) Quantify Concentration and distribution of waste

A sampling and contaminant transport modeling design must be established to quantify relase of hazardous material into various components.

Sampling must be carefully planned to minimize subsequent effort, yet provide the data necessary for accurate assessment of specific remedial action alternatives through the use of contaminant transport models and other assessment techniques. Sampling and modeling designs will vary from site to site because of differences in site-specific features and extent of contamination. Appropriate analytical processes must be identified and arrangements for intensive collection and analysis of samples must be made. Once this framework is in place, contamination of environmental components must be quantified. This quantification must focus on identification of chemicals that can result in the futher degradation of the environment or can affect public wlefare and human health.

(3) Identify risks of site, assuming no futher action

This phase can represent an extensive effort to evaluate the environmental risks of site without remediation; it includes development of priority scores and environmental persistence scores for all waste constitutents identified and characterization of release media and mechanisms. This effort should only be undertaken if the results of this same effort under Phase II were inadequate or inconclusive. For air exposures, the individuals and organisms exposed to the highest toxicant levels are usually those who are closest to the source ; these exposures can be further quantified through the use of contaminant transport models. Once release sources are determined, nearby populations that can be affected are easily located. For soil releases, maximum concentrations are on or adjacent to the waste site. Normally, the site represents the location of peak exposures. For groundwater releases, maximum exposures are usually determined by sampling and analysis and/or contaminant transport modeling. For surface water releases,maximum exposures depend on downstream water uses and may also be quantified using sampling and analysis and contaminant transport models. Both withdrawals and instream uses must be considered. The most toxic and persistent waste constitutents in high concentrations and highly soluble in water are particularly important. Another task is to determine the biotic pathways because living organisms are one way that hazardous substances can move offsite and reach humans. Eventually, potential offsite exposures to humans must be determined, with pathways provided by air, soil, groundwater, surface water, food, and wildlife.

(4) Evaluated environmental conditions affecting remedial actions.

This environmental assessment task should draw on the same types of data as collected for evaluating the environmental exposure/risk of the site without any remediation. The environmental factors that can affect the feasibility of the finite set of remedial action alternatives being evaluated in Phase III must be addressed in detail.

(5) Assess risk and impacts of Remedial Alternatives

From the environmental and public health standpoint, the positive and negative features of each remedial alternative under consideration must be identified; their application must be considered in view of site-specific needs and cost-effectiveness. This environmental assessment of specific remedial action alternatives involves the collection of the same types of data as that collected for the no action alternative. Again, heavy reliance must be placed on contaminant transport modeling to predict the resultant concentrations of contaminants with the various remedial action alternatives. A further step is to rank and select viable remedial alternatives and consider them in relation to the no action alternative. If the no action alternative is eliminated, a single remedial action or a combination of various remedial actions that are environmentally acceptable will be selected for site implementation.

(6) Output

The Phase III characterization efforts are conducted to provide data for selecting remedial actions for a site from the list of feasible alternatives developed during Phase II. The results of Phase III must, therefore, be able to support detailed remedial investigations conducted during the Remedial Investigation activities , as well as support analysis and selection activities conducted during the Feasibility Study. All data collected during Phase III to develop these selections must be well documented. All field and labatory analytical data must be documented in accordance with the Quality Assurance /Quality Control Plan developed for the investigation. The Remedial Investigation should provide input for cost effectiveness analysis and should address : performance, reliability,level of clean -up/isolation achievable, and beneficial effects of response [50].

Notes

[1] 40 CFR 300, p. 697.

[2] 40 CFR 300, p. 685.

[3] Orvis Massey and Gale L. Roberts , Report of Preliminary Investigation of a Hazardous Waste Site, Fulbright Landfil, Springfield , Missouri, State of Missouri , Department of Natural Resources (Springfield Regional Office , September 15, 1980), p. 1.

[4] Final Work Plan (PRP Implementation) " RI/FS Fulbright and Murray Landfills. REM/FIT Zone II Contract, number 68-01-6692; CH_2M Hill, March 14, 1985, p. 1-10.

[5] Massey, op. cit., p. 1.

[6] Ibid., employee interviews

[7] Ibid.

[8] Ibid.

[9] Aerial Photograph, September 24, 1970 (Mission GS-VCME) , number 1-69 and 1-70, Mid-Central Mapping Center, United States Geological Survey, Rolla, Missouri.

[10] Massey, op. cit., interview with Bill Cunningham.

[11] Robert R. Schaefer, Letter to Robert M. Robinson, April 17, 1975.

[12] David L. Coonrod, " Metallic Contaminations in Springfield, Missouri's Inactive Northwest Sanitary Landfill," Paper presented for Geology 481, South

west Missouri State University, 1979, p. 4

13 Alice C. Fuerst, Letter to Lloyd Shadrick, October 19, 1984.

14 State of Missouri, Department of Natural Resources, Divisions of Environmental Quality, Labatory Services Program, Landfill Monitoring Report, Murray Landfill, November 5, 1981.

15 Robert R. Schaefer, Letter to Art Groner, January 28, 1982.

16 Peter A. Krenkel and Vladimir Novotny, Water Quality Management (New York: Academic Press, 1980), p. 62 and 64.

17 Ibid.

18 Massey, op. cit., employee interviews.

19 Ibid.

20 Ibid.

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23 State of Missouri, Department of Natural Resources,Geological Survey, Water Resources and Geology of the Springfield Area, Missouri, Water Resources Report number 34, 1978, p. 2.

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25 Ven Te Chow. Ed. Handbook of Applied Hydrology (New York: McGraw-Hill, 1964) , p. 17-7.

26 U.S. Department of Agriculture, op. cit., p. 2.

[27] U.S. Environmental Protection Agency, Final Environmental Impact Statement, Proposed Wastewater Treatment Facilities, Greene County, Missouri. (EPA 907/9-84-003, June 1984) , p. 9.

[28] State of Missouri, Department of Natural Resources, Geological Survey op. cit., p. 77.

[29] Ibid.

[30] F. M. Henderson, Open Channel Flow (New York: Macmillian Publishing Co., Inc., 1966) , p.96.

[31] Ibid., p. 99.

[32] State of Missouri, Department of Natural Resources, Geological Survey op. cit., p. 20.

[33] Ibid.

[34] U.S. Environmental Protection Agency, op. cit., p. 89.

[35] Allen W. Hatheway, Hazardous Waste Cleanup (Rolla :Course Notes: Geological Engineering 300, University of Missouri , Rolla Press,1985.), p. 3-1.

[36] Roger W. Findley and Daniel A. Farber Environmental Law (St. Paul: West, 1981.), p. 323.

[37] Ibid., p. 234.

[38] Hatheway, op. cit., p. 3-6.

[39] 40 CFR 300.68 (f) , p. 659.

[40] 40 CFR 300.66 (c) (1), p. 655.

[41] Robert Morby, Letter to Dr. David Bedan, May 25, 1984.

[42] David A. Waggoner, Action Memorandum to Morris Kay, September 19, 1984.

43 Tom Gredell, Memorandum to File, April 10, 1984.

44 PL 96-510, 94 Stat 2767.

45 Hatheway, op. cit., p. 6-7.

46 JRB ASSOCIATES, Draft Remedial Investigation Guidance Document. (prepared for U.S. Environmental Protection Agency, February 10, 1984) , p.3-9.

47 Ibid., p. 3-11.

48 Ibid., p. 3-30

49 Ibid., p. 3-42.

50 Ibid., p. 3-52.

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40 CFR 300.1 Environmental Protection Agency Subchapter J. Superfund Programs

40 CFR 257-271 Environmental Protection Agency Hazardous Waste Mangement Standards and Programs.

Remote Images

Historical aerial photographic coverage of the Landfill area was identified through the services of ther Mid-Central Mapping Center of the USGS, Rolla, Mo. Three stereoscopic sets of panchromatic aerial photography were identified:

9 Dec 1960 (mission GS-VADX), photos 1-38 and '1-39.

24 Sept 1970 (mission GS-VCME) photos 1-69 and 1-70

20 Jan 1975 (mission GS-VDTW) photos 1-28 and 1-29.